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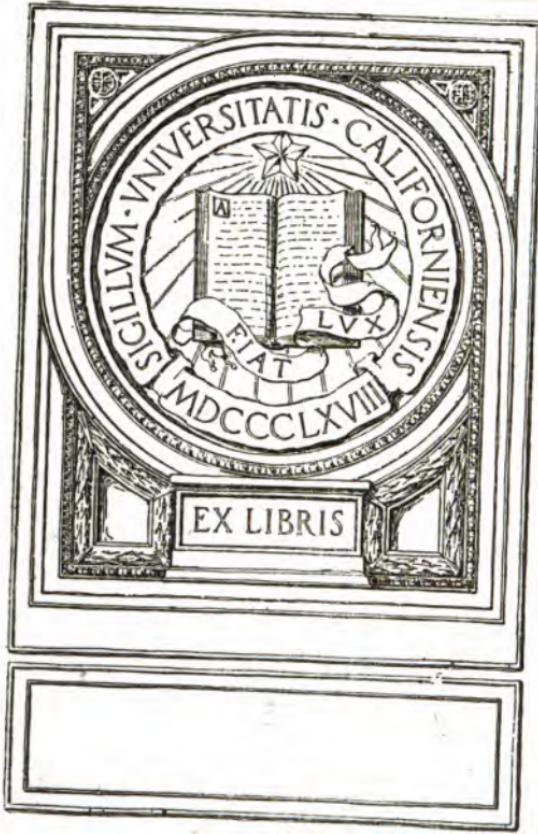
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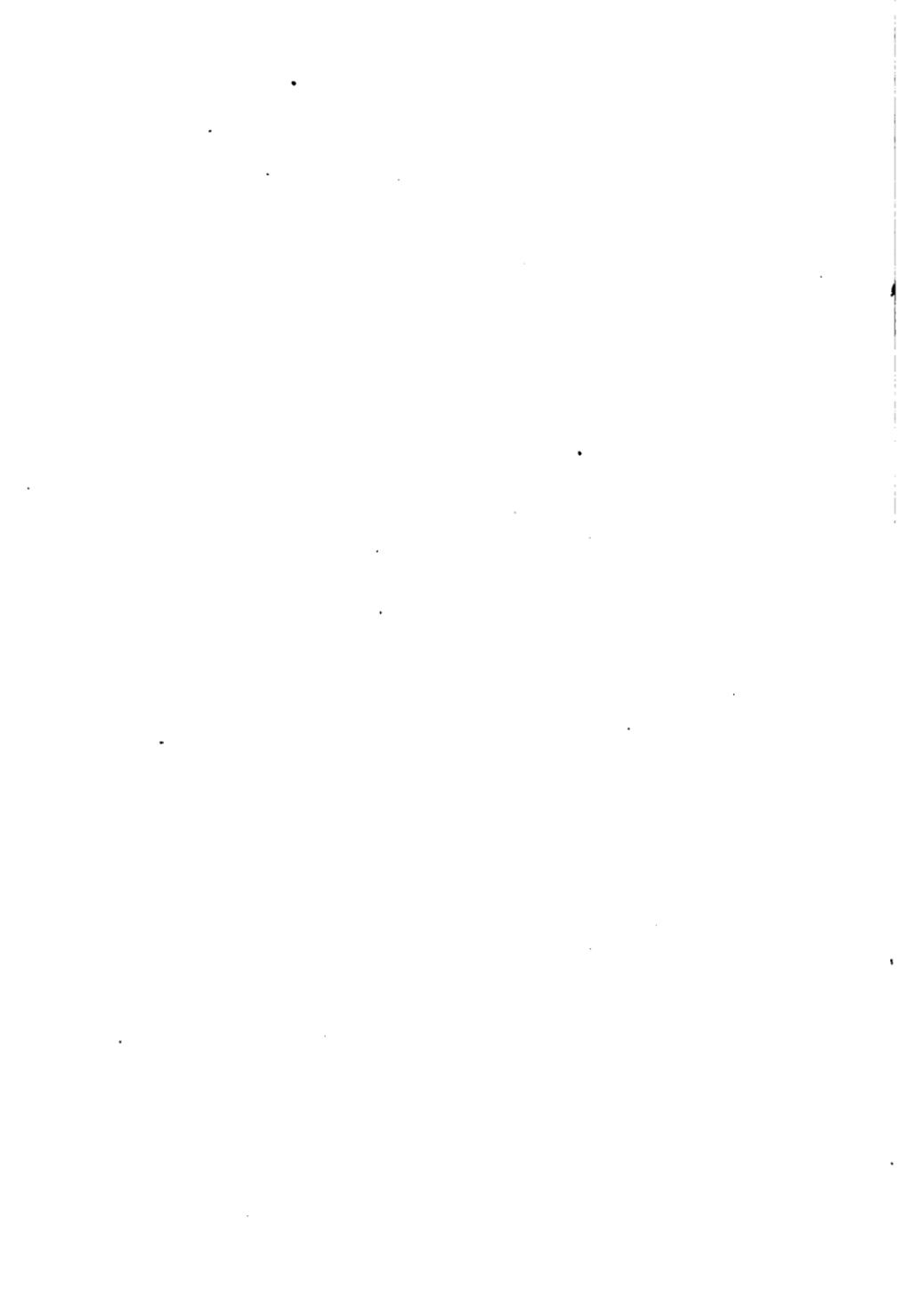
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# GENERAL SCIENCE

## FIRST COURSE

BY

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## PREFACE

THIS book is intended to offer a scientific explanation for the many and varied experiences which pupils of high school age have had and to create a desire for further knowledge of scientific subjects. There is a growing desire among science teachers to have a general introductory course in which the fundamental principles of science and of scientific study are presented in such a way that pupils will acquire the desire for a systematic study of the special branches of science. There are also many high schools in which only a year or so can be devoted to the subject of science. In these a general course giving an explanation of the pupils' experiences with suggestions of how to acquire further information will be most valuable. In many city high schools a number of courses are offered in which no science subject is required. Many of the larger cities are now adding a half-year of general science to these courses in which special science subjects are not required, thus giving such pupils — as in the commercial courses — an understanding of every-day phenomena and some idea of the laws of health. This book is intended to meet these various needs.

After having taught various phases of science, including General Science, for several years and having experimented on the order of arrangement of the subject-matter and the method of presentation, the author has concluded that the arrangement of the material as presented in this book is most effective in securing the following results:

*First.* A desire to grow strong in body and mind and to remain free from disease and to avoid the use of stimulants and narcotics is created. Successful work on the part of many boys and girls is dependent upon this desire becoming strong

enough to rule the body. This desire will be created by the material in the first few chapters if the teacher is of the proper character. Enough material is presented to give the pupils sufficient knowledge and wisdom so that they may know how to protect themselves.

*Second.* A logical method of thinking is developed, so that the pupils have a mind open for the consideration of new facts and principles, thus relieving them of some of their superstitions. Pupils who are taught in a logical manner soon form logical habits of thinking and become able to judge with an accuracy that will surprise many teachers.

*Third.* A desire for more knowledge and further scientific study is created. The fundamental principles underlying scientific knowledge are gradually developed and appear in new forms in various places with new applications. There are sufficient repetitions of the fundamental facts to make the learner thoroughly familiar with them so that he can use them, thus giving him confidence in himself. Self-confidence of the right sort is an absolute necessity on the part of a learner. The author would like to suggest that teachers give a review at the close of each long chapter and also at the close of a number of chapters on related material. *Repetition of fundamentals until they actually become a part of the pupil is a secret of successful science teaching.*

The material which touches upon the pupils' personal habits is placed as early as possible in this course, so that they can use it at the beginning of their high school course and form proper hygienic habits before the four years are passed. The elementary chemistry is placed early in the course in order that a better understanding of the following matter may be had. In connection with chemistry it is not difficult to get an idea of an atom and a molecule. These ideas are fundamental to the study of all scientific subjects and are necessary for a respectable understanding of the chapters that follow. A few chemical symbols have been introduced to give the pupils an idea of the composition of matter. Most pupils have a desire to know the symbols of many common substances. Sufficient material

and explanation are given both in the text and in the glossary for the complete understanding of technical terms used in this course.

When only a half-year is devoted to General Science the author suggests that the order of the book be followed to the end of Chapter XXIV and then if more time remains the teacher can select from the remaining subjects what will be most useful to the pupils. It is hardly possible to cover the entire book in a half year's work so that the pupils will get a definite and lasting impression of the principles underlying the subject-matter.

The field covered in this course may at first sight seem broad and varied, but there are two or three basic ideas which have a broad application and which the mass of simple facts helps to develop into clear concepts. These basic ideas are matter, its properties, and how matter affects other matter,—the reaction of matter upon matter; and energy as a property of matter. Pupils should be required to draw generalizations from known facts wherever possible. The general ideas thus acquired will remain with the pupils, although many of the details may be forgotten. If no generalizations are acquired, the pupil's mind will be blank after the details have evaporated. The pupils who have detailed facts continuously heaped upon them without general truths leave our educational institutions uneducated. They are the ones who may recall that they studied a certain subject while in school, but not much more. Many detailed facts will remain with a general truth through the process of mental association.

The author would suggest that this book is in no case intended to take the place of the live teacher. It is intended to furnish material and suggestions for class discussion and to stimulate the minds of pupils so that they may think about their experiences and acquire more. There are in the course some suggestions which will cause pupils to reflect on the past history of man and to seek for the new in the present and future. The illustrations, drawings and photographs, are given in series wherever possible, so that a more definite idea may be acquired,

and in order to lead to reading in other books which give more details.

The author wishes to express his appreciation to the class of 1917 of the George Westinghouse High School for the inspiration received from them to start this book; to Misses C. E. Kim and Elizabeth Collett for suggestions in English; to his wife and others for reading the proof; to the United States Department of Agriculture, the Westinghouse Motor Company, LaFlam Milk Co., and Mr. Roe for photographs to illustrate the work.

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# GENERAL SCIENCE

## CHAPTER I INTRODUCTION

**Why Study Science?**— This is an age of scientific research and experiment. Science is improving every kind of industry upon which man depends for his physical existence. In many important ways our modern civilization is different from that of our great-grandfathers. This improvement has been made possible by the results obtained from scientific investigations carried on by men who have devoted their lives to the work.

Scientists have improved the means of travel many-fold during the past fifty years. To them we give the credit for our modern railroads, electric lines, swift ocean steamers, airships, aeroplanes, automobiles, and various mechanical devices for making excavations and reconstructions — all in the mechanical realm.

In the field of science that concerns life — that is, in the field of biology — great discoveries have been made concerning plant and animal life processes, the physical structure of plants and animals, and the dependence of man upon microscopic plant forms. Men have discovered many of the microscopic plant forms and animal organisms which produce disease and have learned how to destroy these one-celled enemies of man. Man could

not live in modern conditions without his knowledge of disease germs and how to eradicate them.

The investigations and experiments in agriculture have improved the farming and stock-raising industries so that a sufficient quantity of food can be produced. Experiments in animal feeding have led to the consideration of human feeding and the analysis of human foods.

To live without some knowledge of the general principles of science is like feeling one's way in the dark. To study science is to learn how to understand the environment in which we live and how to adjust ourselves to it and how to improve our physical and social condition. To study science is to learn the basic principles of morality.

The important thing for boys and girls of high school age is to learn how to take proper care of their physical bodies so they may grow to maturity with good health and with a well-developed brain and nervous system. Boys and girls cannot accomplish very much even in high school unless they learn how to take proper care of themselves and how to adjust themselves to their environment.<sup>1</sup> Pupils know that they accomplish their work with difficulty when they have a cold, headache, or indigestion. The pleasantness of school work depends upon continuous effort and a knowledge of how to keep free from disease. If in the first part of this course an effort is made to apply the general principles to your daily life, your school work will not become a burden but a pleasure.

Then why study science?

The answer is: To learn how to live.

<sup>1</sup> See Glossary for words that may seem difficult to understand.



MADAME CURIE, of the University of Paris, who discovered radium.



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GUGLIELMO MARCONI, who invented wireless telegraphy.



EDWARD JENNER, who about 1800 discovered a method of preventing smallpox by vaccination.



LOUIS PASTEUR, who discovered the germs of many contagious diseases and how to kill them.

SOME OF THOSE WHO HAVE MADE USEFUL DISCOVERIES

One definition of science is: *Science consists of systematically arranged knowledge resulting from careful and purposeful observation.*

There are many experiences that pupils of high school age have gathered at random, for which the subject-matter in this course will offer an explanation. Our coming lessons will classify the knowledge gained by accidental experiment and observation, and thus form a basis for future observation and study, either in or out of school.

#### QUESTIONS AND EXERCISES

1. Make a list of the inventors about whom you know something. Name the most important things each one invented, giving the approximate date.
2. Make a list of those who have made important scientific discoveries.
3. Name all of the things at home which have recently come into use.
4. Make a list of the things used in your locality which were not thought of when your grandparents were young.

## CHAPTER II

### **HEALTH**

**1. Meaning of Health.** — When we notice the stream on the hillside, and the many plants and animals about us in the cities and country, we find that everything is busy and active. To have good health is to be active, ready for work. To have good health is to be happy and pleasant, to have no aches or pains to disturb one's activity and work. Would you not like to be in a high school where all the boys and girls have *good health* and never have to stay at home because of sickness?

**2. Value of Health.** — Health is wealth. But the joy and happiness which come to the home where there is no sickness cannot be measured in dollars and cents. If a workman earning twenty-five dollars a week gets sick and is confined to his home for two weeks, what is the cost? Services of the physician, \$20.00; medicine, \$5.00; nurse, \$12.00; extra work for his wife, \$10.00; loss in wages, \$50.00; making a total loss, for the two weeks, of \$97.00 in money, besides the sorrow and suffering in that home. Millions of dollars are wasted every year because people are careless about their health.

**3. School Work and Health.** — Boys and girls cannot do good work in school unless they are healthy and know how to keep healthy. When you feel sleepy because of overwork or because of staying up too late at night, you **cannot** do good school work. Your brain is not at

its best under such conditions. Headaches, bad colds, and indigestion hinder study and success in school work. So do not do the things that cause these troubles. Many boys and girls have to leave school because of bad health which is often due to lack of knowledge of the laws of health and carelessness on the part of the parents and the pupils themselves.

**4. Success and Health.**—Success in life depends largely upon health. Health depends upon habits. Habits are formed in youth. Health is to the future man what the roots are to a tree. The foundation for much of their illness or health in later life is laid by the boys and girls while in school. That instruction which *helps pupils to understand the care of the body, and the value of fresh air, proper food, exercise, and cleanliness, will add much to the wealth of the nation and the future happiness of its people.*

**5. Air and Health.**—Keep out of doors as much as possible. Breathe through the nose, not through the mouth. Have your living rooms well ventilated. Not only purity, but also coolness, dryness, and movement of the air, without a draft, are advantageous. Air in heated houses in winter is usually too dry and may be moistened by having a small vessel of water somewhere on the heater. The minimum clothing that will keep one warm is the best. The more porous the clothes, the more the skin is educated to perform its purpose with increasingly less need for protection. Take an air bath as long and often as possible.

**6. Water and Health.**—Take a daily water bath, not for cleanliness alone, but for skin gymnastics. A cold bath is good, but a short hot bath followed by a short cold one is better. To rest the nerves, take a

neutral bath, beginning with the water at 98° F., and allowing it to cool not more than 5° F.; continue this bath for 15 minutes or more. Be sure that the drinking water is free from dangerous germs and impurities. Ice water should be avoided, especially during hot weather. Cool water, about one-half pint taken half an hour before breakfast and when retiring, is a remedy for constipation.

**7. Food and Health.** — Form the habit of masticating all food until it is swallowed without conscious effort. Give as much attention as possible to the taste rather than to the chewing. Food should simply be chewed and relished, with no thought of swallowing. There should be no more effort to prevent than to force swallowing. It will be found that if you attend only to the agreeable task of extracting the flavors of your food, nature will take care of the swallowing, which will become involuntary like breathing. Many people have their habits of eating and appetite perverted by hurry and by the use of "abnormal" foods. The best results from meals can be secured only by not feeling hurried and by taking sufficient time for thorough mastication. Liquid foods should be mixed with saliva before swallowing.

The stomach, like any other part of the body, needs rest, and so the meals should be far enough apart to grant time for this rest. The stomach can digest with ease thoroughly masticated food. *Keep your stomach clean by not allowing anything to go into it except pure food and drink.* A healthy stomach means few headaches and very few, if any, diseases.

#### QUESTIONS AND EXERCISES

1. Carefully observe in your school whether the best work is done by the boys and girls who are healthy or by those who are absent often because of sickness.

**GENERAL SCIENCE**

- 2.** Make a list of the successful business and professional men and women in your community and see how many are healthy and how many are sickly.
- 3.** Make a careful estimate of the cost of the last sickness in your own home. (See § 2.)
- 4.** What is your conclusion now about the value of health?
- 5.** Is your home properly ventilated? Why?
- 6.** Do you use water properly for drinking and bathing? Why?
- 7.** Do you use the right kind and proper amount of food? Why?

## CHAPTER III

### CHEMISTRY OF COMMON THINGS

**8. Chemistry** is the science which treats of the composition of substances. All substances are made up of very small bodies or particles. If you place some water in a vessel on a hot stove, the water will rapidly escape by evaporation. How does it get out of the vessel? The water on the road or sidewalk soon disappears after a summer shower. Where does it go? How does it get away? What other substances can be made to evaporate? As you can divide a quart of water into drops, so you can divide the drops into smaller bodies, and by the use of heat the water can be divided into such tiny particles that they can fly away in the air and not be seen.

You can take a piece of chalk or wood or coal and divide it so that you would need a magnifying glass or microscope to see the smallest parts. But the smallest parts are still chalk, wood, or coal, like the large piece from which they came. If you hold a cold piece of iron over a vessel with boiling water in it, the particles of water escaping will collect on the iron in drops, and these drops will be water the same as that in the vessel. This shows that the little particles escaping from the water in invisible form are water. These little particles of water, chalk, and coal which are too small to be seen with the best microscopes are called molecules.

**9. Molecules.** — Molecules are the smallest divisions of a substance that have the same properties as the substance itself. The small, invisible particles that escape when water is heated are called molecules of water. The smallest parts of chalk, coal, or sugar that have the properties of chalk, coal, or sugar are also molecules. Many thousands of them could hang on the point of a pin.

**Why do these molecules escape when the water is heated?** — If a dozen boys and girls were standing on a platform just large enough to hold them, they could all stay on as long as they did not move around too much. But however quiet they might try to be, there would still be some movement, though perhaps not enough to shove them out of their position. When they become more active and begin to move around on the platform, several may have to jump off. The more active they get, pushing against one another, the smaller the number that can stay on the platform, and in time only one may be left.

In a piece of ice (a solid) the molecules can move out of their position, but not far — not even far enough to change, materially, the shape of the ice. When heat is applied to the ice, the molecules become more active, and finally they shove one another so far apart that the ice loses its shape and becomes a liquid. In a liquid the molecules move around so freely that the liquid will take the shape of any vessel containing it. Since molecules of water are so small and light that they can float around in the air, some of them jump out of the liquid into the air and fly away.

The process by which molecules continually escape from water into the air is called *evaporation*. The more heat you add to the water, the faster the molecules move, and hence they escape into the air very rapidly.

when the water is boiling. When water boils steam is formed. Steam consists of water molecules which are moving so fast, and in every direction, that if they should bump against one another they would bounce apart again like two flying baseballs. If they should strike a wall or any other object, the molecules would rebound the same as a baseball does when thrown against an object.

The molecules composing steam are free to move in every direction. Steam is a gas. The molecules of gases are very active. If illuminating gas is turned on in the house without lighting it, you can soon smell it because the molecules spread all through the house. When perfume and ammonia bottles are opened, some of the molecules escape and travel through the air with great speed. They can easily be detected by the smell.

In solids the molecules move slowly and within a very limited space. In liquids the molecules move with greater speed than in solids, and they move around and over one another with ease. In gases the molecules move with very high speed, much greater than in liquids, and rebound from one another or from any object that they may strike.

**10. Atoms.** — Molecules of most substances such as water, sugar, salt, and chalk are not simple molecules but complex ones. These complex molecules can be divided into more simple forms. But when the water molecule is broken up into its more simple forms, these simpler forms do not have the properties of water as the molecule does. The same is true of all other complex molecules. The simpler forms do not have the same properties as the molecules. These simpler forms or divisions of the complex molecules are called *atoms*.

When a substance is composed of atoms which are all alike, the substance is said to be a simple substance or *element*, such as iron, gold, lead, silver, oxygen, hydrogen, sulphur. When a substance is composed of molecules made up of two or more different kinds of atoms, it is said to be a compound, such as water, salt, sugar, chalk.

Molecules are very small, but atoms are smaller than most molecules, as many molecules are made up of two or more atoms. A molecule of common salt has two atoms, while a molecule of cane sugar has 45 atoms.

In ordinary chemistry the atom is the smallest division that can be made of any substance. So the atom is the smallest chemical unit. The kind and number of atoms that are used to make a molecule determine the nature or properties of the molecule and hence the properties of the substance. Most substances used by man are composed of complex molecules and so they are called *compounds*. These compounds are classified according to their own properties and according to the way in which they affect other substances or compounds. Most of the compounds discussed in this book can be classed as acids, bases, and salts.

**11. Acids.** — Acids occur in plants, in animals, and in the earth. Citric acid is found in lemons and oranges and gives them their sour taste. It can be prepared from lemon juice, and consists of beautiful crystals which will easily dissolve in water. Malic acid is present in sour apples. Grapes contain tartaric acid, which is used in making cream of tartar and baking powder. The jack-in-the-pulpit and rhubarb contain oxalic acid. Lactic acid is formed when milk sours. Lactic acid is also found in the muscles of man and other animals.

Vinegar, which is made mostly from apple juice, is a dilute solution of acetic acid. Hydrochloric acid<sup>1</sup> (HCl) is formed by the gastric glands of the human stomach to aid in digestion. The air contains small amounts of carbonic acid gas, and where much coal is burned the air contains some sulphur dioxide. Some spring waters contain carbonic acid, while soil waters contain various acids from the decay of plants and animals. The acids taken from plants are made up of molecules which are very complex. Those that are called common acids have molecules that are more simple.

The chemical symbols for acids, as well as for other compounds, show the number of the atoms in the molecules. Some common acids are hydrochloric acid (HCl), sulphuric acid ( $H_2SO_4$ ), nitric acid ( $HNO_3$ ), and acetic acid H( $C_2H_3O_2$ ).

**Tests for acids.** — *Litmus* is a substance taken from the group of plants called lichens. A solution is made of the litmus coloring matter, then paper that has been prepared for the purpose is dipped into the litmus solution and allowed to dry; this colored paper is called litmus paper. The common acids and nearly all other acids will turn litmus paper from blue to red.

Very dilute solutions of the common acids taste sour. Fruit acids are all sour. Sulphuric acid and nitric acid, when strong, will make a brown spot on wood, paper, or clothing, and will also injure any part of the body which they touch. For this reason it is very important to learn the nature and properties of another group of



LICHENS  
These forms grow on rocks, bark, and wood.

<sup>1</sup> See Glossary, under heading "Chemical Symbols."

compounds, called bases, which will neutralize the acids and prevent their destructive action.

**12. Bases.** — Bases, or alkalies, are substances or compounds such as household ammonia ( $\text{NH}_4\text{OH}$ ); potash lye ( $\text{KOH}$ ), which is also called caustic potash; soda lye, or caustic soda ( $\text{NaOH}$ ); and slaked lime ( $\text{CaO}_2\text{H}_2$ ), which is used for building purposes.

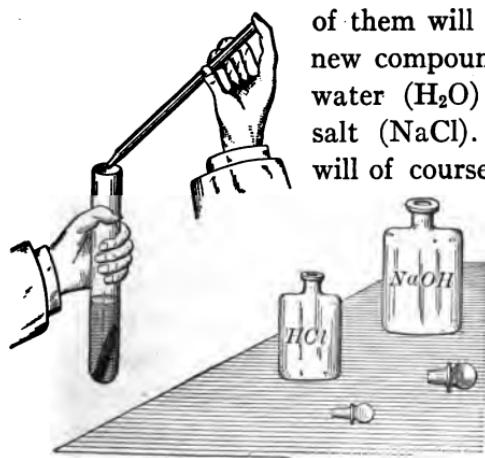
In the home the bases are more commonly used than the acids. They are used largely for cleansing purposes, and potash lye is used for making soap. The lye, properly diluted, is very valuable for removing grease from drain pipes and sinks. Household ammonia is ammonia in diluted form, and a small amount in water is very useful for house cleaning, and also for washing delicate fabrics and for the removal of stains and grease spots.

The strong bases, like the acids, must be used with considerable care and caution. If they come in contact with the hands or clothing, they have a caustic or "eating" effect and usually will discolor the clothing. If a base is spilled, it can be neutralized by pouring on it at once some dilute acid. The best acids to use for this purpose are hydrochloric and acetic acids. In the home, lemon juice or vinegar would do. If any acid is spilled, it can be neutralized by pouring on it at once a base. Ammonia is the best, as it is the least harmful if too much of it should be used. The strong acids and bases act very quickly on the body and clothing, and in case of accident the neutralizer must be used without delay or the harmful work will be done and there will be no remedy. A base will neutralize an acid and an acid will neutralize a base. Limewater, a mild base, is sometimes prescribed by physicians to neutralize the acids in the stomach and thus aid digestion.

Bases in dilute form have a bitter taste and some (potash lye and soda lye) have a soapy, slimy feeling. Bases will turn red litmus paper blue. If blue litmus paper is dipped in acid it will become red. This red litmus paper, if placed in a base solution, will turn blue. Bases will turn colorless phenolphthalein<sup>1</sup> red and acids will make the red disappear. This is a very delicate test for a base. Acids and bases react on each other in such a way that the one undoes the work of the other.

**13. Neutral Substances.**—Neutral substances are formed by the interaction of a base and an acid. For instance, when the proper proportions of hydrochloric acid (HCl) and caustic soda (NaOH) are poured together in a vessel, two new substances will be formed and both

of them will be neutral. The two new compounds thus formed are water ( $H_2O$ ) and common table salt (NaCl). The common salt will of course be dissolved in the water, but can be made to crystallize if the solution is heated so that the water evaporates.



FORMING A NEUTRAL SUBSTANCE

By mixing a base and an acid.

a test tube or other vessel a small quantity of an acid and then place in it a small piece of litmus paper and note the color. Now slowly pour in a base

<sup>1</sup> See Glossary.

solution, until the litmus paper turns blue. Take a dropper, made out of a small glass tube, and put in acid drop by drop until the litmus begins to turn red. If you get in too much acid, use a small drop of the base. When the solution is neutral the litmus paper will have a bluish-red color. When you think the solution is neutral, put in a few drops of phenolphthalein, which will remain colorless if the solution is neutral or if it has an excess of acid. If there is the least excess of base, the phenolphthalein will turn red.

From our study of acids and bases we learned that they will corrode or rust metals, discolor clothing, and even eat a hole in it. But none of these three things will be done by a neutral substance or a substance almost neutral. The three unfavorable effects of strong bases will show us why they cannot be used generally for washing clothing or bathing. So a milder cleansing agent, namely soap, which will remove the dirt without injuring the clothing, has been made.

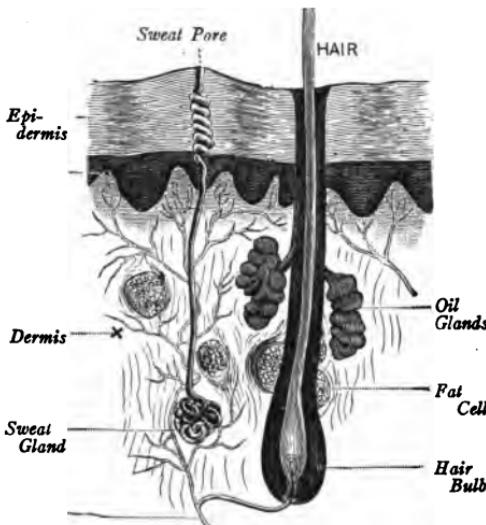
**14. How Soap is Made.**—Fats or oils taken from plants or animals, and a base (soda lye or potash lye) are used in soap making. Fats are salts in which glycerine acts as the base and stearic, palmitic, and oleic acids act as acids. When fats are heated with caustic potash ( $KOH$ ), glycerine is formed and set free, while the potassium of the potash unites with the acids of the fat and forms a salt called soap. The oxygen and hydrogen of the caustic potash help to form the free glycerine. The soaps made with caustic potash are soft soaps. When fats are heated with caustic soda ( $NaOH$ ), glycerine is formed and set free, while the sodium unites with the acids of the fat and forms hard soap. Hard soap can also be made by using potash lye, if common

salt is added when the soap is through cooking. While cooling the soap will rise to the surface and leave the brine, alkali, and glycerine in the solution. Liquid soap is made by adding water to the soft soap until it flows as freely as desired. Liquid soap is more sanitary than hard soap, especially in schools, railroad stations, and other public buildings, as it prevents more than one person from handling the same soap.

Cheap laundry soaps are made of resin and waste lard, butter, tallow, scraps of meat, waste fat, and kitchen refuse and an excess of a strong base. The excess base makes them very hard on the hands and also on fine fabrics. Fine

toilet soaps are made of pure plant oils and enough of the base to make them almost neutral but leave them slightly basic. (Ask your teacher or parents to tell you how your great-grandparents used to prepare potash for soap making.)

**15. How Soap Cleans.** — The hands, face, and other parts of the body are kept soft by an oil which is secreted by the glands in the skin. When the hands and face are washed several times without soap, as when out camping,

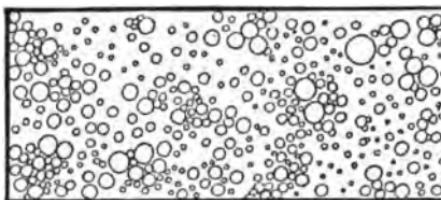


VERTICAL SECTION OF THE SKIN

Note the relative size of the oil glands.  
(Magnified.)

this oil is not removed from the skin and so the water cannot remove the dirt. To understand how the soap removes this oil it will be necessary to know what an *emulsion* is and how it is made.

When little particles of fat are broken up so finely that they seem to mix and disappear in water, *this mixture of particles of fat and water is called an emulsion.*



GLOBULES OF FAT IN MILK

A good type of an emulsion. (Magnified.)

Milk is a typical example of a good emulsion in which the fat globules rise to the surface as cream, if it is allowed to stand for several hours. An emulsion can be made by taking some oil and

shaking it with some base in a test tube. The base breaks up the oil into fine globules so that they mix with the solution easily.

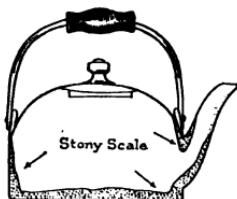
Since all soaps are slightly basic, the base acts on the oil or grease on the hands and face and forms an emulsion which mixes with the wash water and then the water easily takes the dirt away also. The same is true of the removal of dirt from clothing, except that usually a soap is used having a greater excess of base, which forms an emulsion of the grease in the clothing and sets the dirt free.

Nearly everyone is familiar with the fact that soap does not work well in all kinds of water. In some water soap will easily form an emulsion of fat and also a good lather or soap foam. This water is said to be "soft" water, and it does not contain any chemical that will act on soap and prevent the formation of an emulsion.

The other kind of water contains chemical compounds which will act on soap and prevent the formation of an emulsion. This water is said to be "hard" water, and a lather will not form in hard water or in water containing chemicals that act on soap.

**16. Hard Water.** — Water flowing over the ground and through the ground comes in contact with more or less salts that can be dissolved and carried along in solution. If these salts held in solution happen to be what are known as the calcium salts, as calcium hydrogen carbonate [ $\text{CaH}_2(\text{CO}_3)_2$ ], or calcium sulphate ( $\text{CaSO}_4$ ), which is also known as gypsum, the water will be "hard" water. When soap is used in hard water a sticky, gummy-like substance is formed which will not dissolve in the water and which is known as calcium soap. Calcium soap is not fit for washing as it will not form an emulsion with fats. In hard water the soap is wasted until the calcium compounds are all broken up by the soap. This is an expensive way of making the water "soft," so cheaper chemicals are used to soften water.

Water containing calcium hydrogen carbonate [ $\text{CaH}_2(\text{CO}_3)_2$ ] is said to be "temporarily hard" because it can be softened by adding a measured quantity of slaked lime ( $\text{CaO}_2\text{H}_2$ ), or by boiling it for a time. The slaked lime acting on the calcium hydrogen carbonate forms a white precipitate, calcium carbonate ( $\text{CaCO}_3$ ), which will settle, and then you may draw off the clear, soft water. The stone-like scale in a teakettle in which hard water is continually heated is due to the settling of the insoluble compound, calcium carbonate, ( $\text{CaCO}_3$ ) formed



TEAKETTLE

Showing the stone-like scale from hard water.

by the action of the heat on the calcium hydrogen carbonate.

Water containing calcium sulphate, or gypsum ( $\text{CaSO}_4$ ), is said to be "permanently hard," because it can be softened only by removing the water from the gypsum by distillation or by adding some substance such as borax, ammonium carbonate, or washing soda ( $\text{Na}_2\text{CO}_3$ ), also called sodium carbonate. These substances are cheaper than soap and they break up the gypsum and form substances which will not act on soap. But these new substances are hard on the clothes and also on the hands of the laundry workers, so it is better to use "soft" water.

**17. Salts.** — A number of compounds which can be classed as salts have already been mentioned. Salts are formed by the interaction of a base and an acid. If, as described in §13, just enough base is used to neutralize the acid, a neutral salt is formed. Common salt and sal ammoniac and gypsum are examples of neutral salts. If an excess of a base is used with an acid, a basic salt is usually formed. If an excess of an acid is used, an acidic salt is usually formed. Cream of tartar is an example of an acidic salt.

There are great quantities of common salt and other salts stored in the earth, which have been there for long ages. Salt is taken from the earth in various parts of the United States by drilling wells and pumping out the salt water, by digging mines, and in California it can be shoveled from the surface. The salt water or brine is allowed to evaporate and then the salt will form in crystals. The largest salt mines are in Germany, where the salt is about a mile deep. This salt was perhaps deposited during the evaporation of an ancient inland sea, such as the Caspian, or the Great Salt Lake in Utah.

Great quantities of common salt are used in cooking and preserving meats and other foods, but much more is used in the manufacture of washing soda, soap, glass, bleaching powders, baking powders, baking soda, etc. About 4,000,000 tons are used annually in the United States alone.



MAKING SALT BY EVAPORATION IN CALIFORNIA

### QUESTIONS AND EXERCISES

1. Your mother hangs wet clothing on the line to dry. Where does the water go? What becomes of sweat on your body?
2. Test with litmus paper the compounds which you have at home. (Dry substances must be dissolved in water. Test the water before using to see if it affects the litmus.) Make a list of them as follows:

<i>Name of compound</i>	<i>Acid</i> .....	<i>Base</i> .....	<i>Neutral salt</i> <sup>1</sup>
Baking soda.....	(   )?	(   )?	(   )?
Vinegar.....	(   )?	(   )?	(   )?
Soaps.....	(   )?	(   )?	(   )?
Etc.			

<sup>1</sup> Neutral salts do not affect red or blue litmus.

3. Make some soap by boiling a mixture of lard and some strong base, as potash. (To see if the soap is done, mix a little of it with soft water. If no fat globules appear on the surface of the water the soap is ready for use.)

4. Make an emulsion by thoroughly mixing a fat or oil with some base and water. Let it stand a few hours to see if the fat will come to the surface.

5. If you have no hard water, make some by adding a few drops of some acid or calcium sulphate solution, and divide the water into two parts. Try some soap in one part and observe the result. Place some washing soda in the other part and then try soap in it. Now compare the result with that of the first trial.

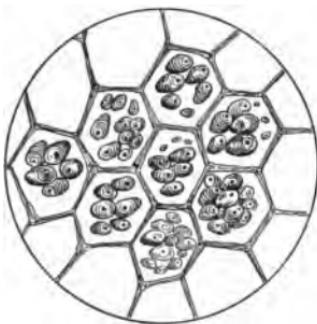
6. Examine the inside of your teakettle to see if any hard substance has collected on the bottom and sides. If so, what is it?

## CHAPTER IV

### CHEMISTRY OF BAKING

**18.** Cooking improves the flavor and makes more digestible most articles of food. There are two ways of preparing food from plant sources. One is to heat it in water or other liquid, which softens the connective tissue so that it is easily broken up and the cells set free for the action of the digestive fluids of the body. The other way is to subject the food to dry heat, as in an oven, where a much higher temperature than that of boiling water can be obtained. Plant foods prepared in the oven have some water or moisture in them, as liquids are used in mixing the various kinds of flours. Even popcorn, though very dry, bursts open when heated, because the moisture in it turns into steam.

The heat causes the starch grains of vegetables and grains to enlarge and burst the connective tissue holding them, and also changes a little of the starch into a form of sugar called *dextrin*, and the part remaining is then easily changed to sugar by the digestive fluids. Striking examples of this change of starch to dextrin sugar are the differences in taste between a raw and a cooked



STARCH GRAINS

In cells of potato as they appear under the microscope.

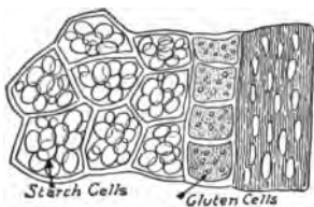
potato, and raw flour and bread well baked. This dextrin sugar, formed in the bread while baking, is turned into caramel on the surface of the loaf, where the temperature is very high, and gives to the bread crust the brown color. Caramel is also formed when bread is toasted.

Bread made from corn meal is not porous or full of small holes like bread made from wheat flour. Wheat flour has in it a form of albumin called *gluten*. This

gluten when moistened is very tough and gummy and does not permit the gases formed in the dough to escape. The gas formed in the dough raises it. When the dough is placed in the oven, the gas in it expands because of the intense heat and so raises the dough still more,

so that the heat can affect the starch and albumin in all parts of the loaf,—that is, bake it clear through. There are several ways of forming this gas in the dough; these may be classed as follows: 1. By the use of chemicals. 2. By the use of a one-celled plant (yeast). 3. By a mechanical method such as is sometimes used in baking cakes, viz. beating the dough violently to get air mixed with it, which will expand when the dough is placed in the oven, and thus raise it.

**19. Baking Soda ( $\text{NaHCO}_3$ ).**—Baking soda is also known as bicarbonate of soda and sodium hydrogen carbonate. It is a salt, slightly basic in its reactions on other compounds. When it is acted on by an acid, such as sour milk, carbon dioxide is set free. If it is mixed with the dough without the use of a mild acid, the carbon dioxide will be liberated by the action of the heat while



A GRAIN OF WHEAT

Showing starch and gluten.  
(Magnified.)

baking. The carbon dioxide is what raises the dough when baking soda is used. If the soda is not completely dissolved and mixed with the dough, yellow spots will appear in the bread or biscuits. One sure way of preventing this is to dissolve the soda in water and then mix it with the flour or dough. A less sure way of preventing the yellow spots is to sift the soda with the flour.

When baking soda in solution or in the dough is heated, carbon dioxide is liberated, and another salt called washing soda ( $\text{Na}_2\text{CO}_3$ ) is formed. This stays in the bread and is not healthful.

**20. Baking Powder.** — Baking powder is a mixture of two salts and some corn starch to keep it dry. Baking powder does not form washing soda in the bread and so is better for baking than soda. The object in using any such compound in baking is to liberate carbon dioxide to raise the dough. Carbon dioxide will be liberated if baking soda is used with an acid. Hence, in making baking powder, baking soda is mixed with a mild acid salt which will not form a harmful salt in the bread. (*Caution.* — Sometimes in making baking powder a cheap acid is used that will form a harmful substance in the cake or bread. These are called the *alum baking powders* and they should not be used.)

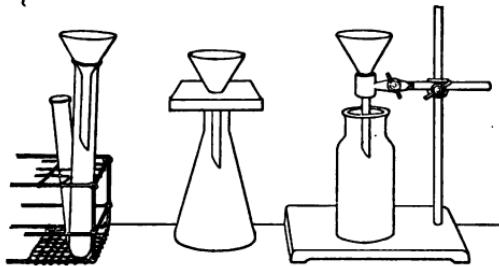
The good baking powders are made of *two parts of cream of tartar* ( $\text{KHC}_4\text{H}_4\text{O}_6$ ), *one part of baking soda*, and some corn starch. Tartaric acid ( $\text{HC}_4\text{H}_4\text{O}_6$ ) and calcium acid phosphate [ $\text{CaH}_4(\text{PO}_4)_2$ ] may also be used with baking soda to make the baking powder. The substances formed in the bread by these powders are perfectly harmless.

In making baking powders baking soda is mixed with the acidic salts, but no chemical action will take place

while they are dry. If water is mixed with the powders, a reaction will occur during which all the carbon dioxide will escape. For this reason baking powder should be thoroughly mixed with the dry flour before making the dough, then the carbon dioxide will not be formed so rapidly and will not escape. Self-rising flour has baking powder mixed with it.

*How to test baking powders for alum.* — Burn two or three grams of the powder in a porcelain dish. Mix the

ash left in the dish with boiling water and filter. Add to the filtrate (the filtered solution) enough ammonium chloride solution so the mixture will have a distinct odor of ammonia.



FUNNELS FOR FILTERING

Three ways of supporting them.

Look for white flakes in the solution. If none appear immediately, warm the solution slowly. These white flakes, if any, are composed of an *alum compound* and indicate the presence of alum in the baking powder.

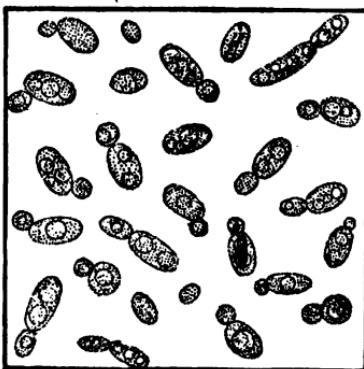
**21.** Baking soda and baking powders are used only when not much time is taken and in baking in small quantities such foods as cakes, pies, biscuits, and corn bread. They are used in making corn bread because corn meal does not have any albumin in the form called gluten to hold the carbon dioxide set free by the slow action of yeast. The corn bread must be baked as soon as the mixture is made.

There are several reasons why baking powder is not

used in making "light" bread. It would require such a large quantity of it to raise the dough that it would be much more expensive than yeast. The taste of biscuits baked in a few minutes after mixing the dough is quite different from the taste of bread which has been given several hours for the dough to rise. This difference in the taste of "light" bread and biscuits is due to three things. 1. Growth of the yeast plant takes place in the dough. 2. The wheat grain has a ferment in it called *diastase*. This diastase is in the flour made from wheat, and it changes some of the starch in the flour to sugar while the bread is rising. It takes several hours for the diastase to change much of the starch to sugar, and so it does not have time to act in the quickly made biscuits. 3. Heat changes starch to dextrin sugar, but it must have time to do so.

The heat has a longer time to act on the large loaf than it does on the small biscuit.

**22. Yeast.**—Yeast is a plant so small that a good microscope is necessary to see it. It consists of only one cell. The plant grows by each cell dividing into two unequal parts. The smaller part is called a bud while attached to the larger part. When a yeast plant does not have food enough, it grows a tough protective covering over itself, and then can dry sufficiently to be carried by the wind with the dust and float about in the air. On this account the air is full of yeast plants, but they are



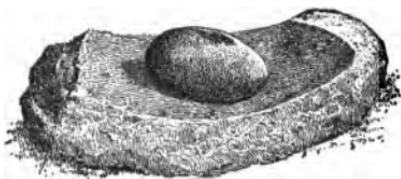
YEAST PLANTS  
(Magnified.)

so small that they cannot be seen. These floating yeast plants are called wild yeast. When they fall into liquids containing small quantities of sugar they start to grow and soon spoil the liquids. While yeast is in the air or on dry material, it remains inactive, just as do seeds that are not planted. When it falls in places favorable for growth, it throws off its protective covering and absorbs the food. The conditions favorable for its growth are:

1. Temperature from 70° to 100° F. (*Bread rises best in a temperature of from 80° to 95° F.*)
2. Moisture in sufficient quantity to dissolve the food.
3. Food in solution.

When these three conditions are present a few yeast plants will soon increase to thousands. While they are growing, they give off two waste products. The important one in bread-making is carbon dioxide gas. This gas causes the dough to expand and become spongy, thus making the bread light and porous after baking. The only reason why yeast is used in baking is because of this carbon dioxide gas which it forms in

the dough. It also gives off alcohol as a waste product. But so little of this is formed in the dough while rising that it is all driven out by evaporation during the



ANCIENT GRINDING STONES

process of baking. Alcohol boils at a lower temperature than water and so will evaporate faster and more easily.

**23. History of Bread Making.** — The ancients made bread in a way somewhat similar to the method of the savage tribes of today. They crushed the grain with a hand tool of wood or stone and made a paste of the meal with water and then baked it by holding it over a fire.

The result was a hard, compact mass called unleavened bread, which was very hard to masticate, and the taste was not that of modern bread. If the paste made of water and crushed grain was allowed to stand for a few hours, the wild yeast of the air would fall into it and start to grow and produce carbon dioxide gas. This made a more porous loaf than the unleavened bread and was a great improvement over it. It was called self-raised bread.

This was discovered perhaps by some good housewife who, after making her batter, had to attend to some other duties for a few hours and on returning found that her dough had increased in size. This she baked and found that it had a better quality than any she had ever tasted, so after this she let all of her dough stand a few hours before baking, and of course told her neighbors about her new bread.

Soon it was also learned that if a bit of this self-raised dough was saved and put into the next baking, the batter would rise much faster and be much more porous and eatable than the self-raised bread. This was another great improvement and was widely used for many centuries. It is used somewhat even today. A very similar method was used by the Romans. They learned that grape juice mixed with millet would grow yeast plants rapidly, so they used this mixture for bread raising by kneading a small quantity of it into the dough, then allowing the dough to stand a while before baking.

Through all these centuries the results of fermentation were known and used, but it was not known that the yeast plant was the cause, nor until the nineteenth century did anyone know that there was such an organism as the yeast plant. The microscope was necessary to discover the little plant in fermenting liquids, to learn

how it grew, and that it could change sugar into alcohol and carbon dioxide. Alcohol was known ages ago, but it was not known that alcohol is a poisonous waste-product of the yeast plant.

The yeast was studied until a way was found by which it could be grown in great amounts for bread making and for the production of alcohol and the various intoxicating drinks containing alcohol. The commercial yeast in the form of cakes consists of a great number of yeast plants without sufficient moisture and food for growth. When this commercial yeast is mixed with dough, the yeast plants begin to grow and increase rapidly, giving off carbon dioxide which raises the batter, and when this is baked it is our modern bread.

#### QUESTIONS AND EXERCISES

1. Taste the brown crust of well-baked bread, and then the white inner part. Make note of any difference.
2. Examine the texture of wheat bread and that of corn bread. Explain the difference and its causes.
3. Dissolve some baking soda in water and observe the result. Now add a few drops of vinegar. Explain what happens. What made the bubbles?
4. Dissolve some baking powder in water. Does it act the same as baking soda? Why?
5. From what you have observed, how should baking soda and baking powder be put into the baking material?
6. Why do good soda biscuits taste different from raised bread?
7. Dissolve a teaspoonful of sugar in a gill of water and mix with it a small quantity of yeast. Place it for a few hours where the temperature is  $70^{\circ}$  to  $95^{\circ}$  F. Note and explain the gas bubbles.
8. If you have a microscope, place one drop of the solution on a glass slide and examine.

## CHAPTER V

### PRESERVATIVES AND DISINFECTANTS

**24. Germs.** — The world is full of many kinds of microscopic living organisms. They are one-celled bodies. Some are animals and some are plants. The one-celled

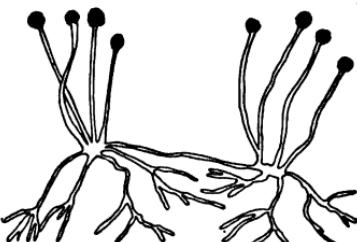


BACTERIA OF VARIOUS KINDS

Magnified 1000 diameters.

plants are known as *bacteria*. Most of the bacteria are very valuable and serviceable to man. Some of these are in the soil and prepare food for the trees and vegetables and grains upon which man is dependent for food. Others are useful in souring milk, ripening cheese, and making cider vinegar. Others decompose dead matter, such as fallen trees, grass, and dead animals, and thus prevent them from collecting in quantity on the earth.

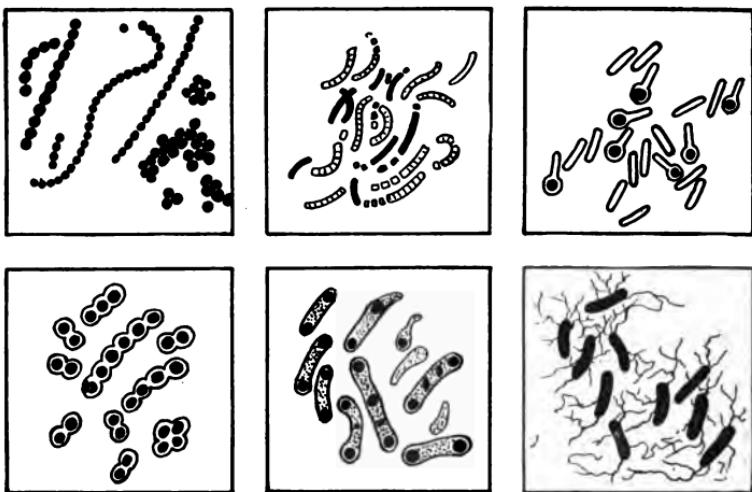
But when these act on things which man wants to keep, then they are considered harmful. They will decompose railroad ties, telephone poles, all kinds of wood fixtures, meats, and other foods. Mold is also very destructive. It will destroy bread, damp clothing, fruits, etc. The yeast plant is also responsible for the souring of



MOLD PLANTS

(Magnified.)

fruit juices. In order to protect his property, man had to find ways of preventing the growth of these tiny plants called yeast, mold, and bacteria. A few bacteria and one-celled animals live as parasites in man when they get a chance, and are called disease germs. Each kind causes a different disease.



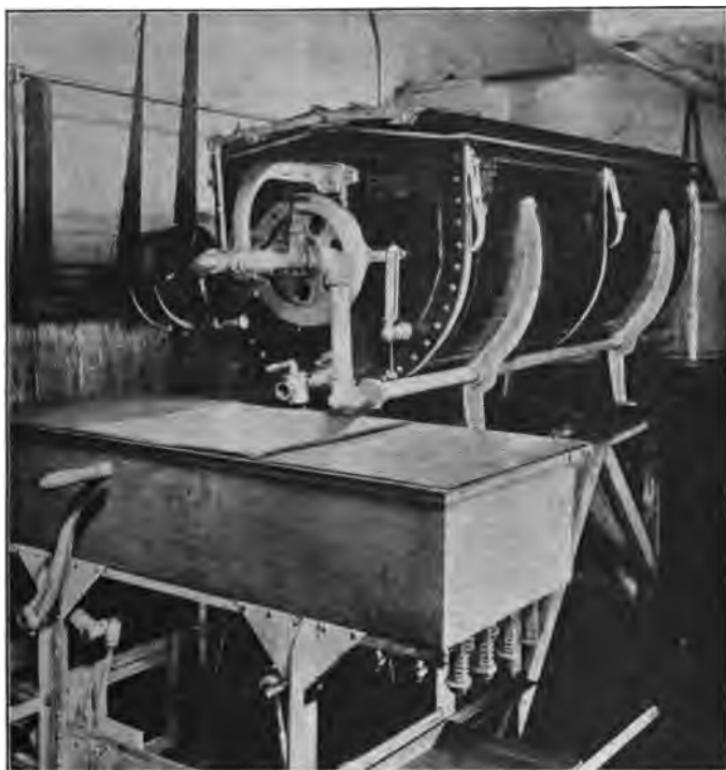
TYPES OF GERMS

From left to right, top row: Pus, Tuberculosis, Tetanus; bottom row: Pneumonia, Diphtheria, Typhoid.

Many physicians are spending their lives in studying disease germs, and some wonderful results have been accomplished. These physicians tell us that it is much easier to prevent disease than it is to cure it. When the germs get into our bodies, they are very hard to kill without injuring the body. Some germs the physicians are not yet able to kill while they are in the human body, and the diseases caused by such germs are said to be incurable. What are some incurable diseases?

The air contains many of these dangerous germs be-

cause of the carelessness and ignorance of so many people. They get into the water we drink and the food we eat. Our bodies are able to kill these germs by thousands if we keep healthy by regular habits of exercise and sleep,



PASTEURIZING AND BOTTLING APPARATUS FOR MILK

The milk is kept at  $140^{\circ}$  F. for thirty minutes. About 98 per cent of the bacteria are killed. (From La Flam Creamery.)

and take nothing into our bodies but pure food and pure water.

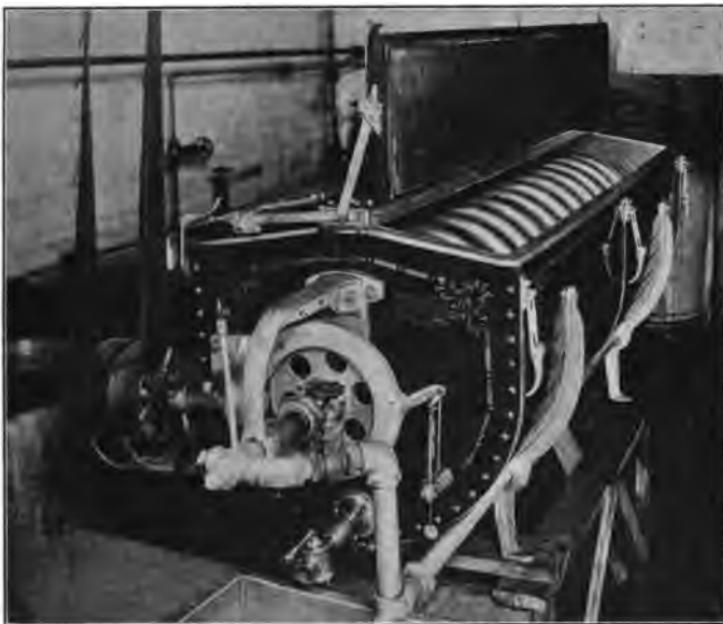
**25. How to Destroy the Germs.** — Since the germs are very numerous and so many people are not healthy and so many are careless, it will be well to know how to

keep them out of our bodies. They are much more easily killed if where we can get at them than when they are in the body. Since many of the germs live best in dark, moist places, sunshine is the best natural germ destroyer or disinfectant that man can use. Let the sunshine into the rooms of all buildings. The faded paper on the wall will not cost as much as sickness and moderately poor health. Hang clothing, carpets, and bedclothes in the sunshine and air. The wind and sunshine work together killing germs.

(A) *Germs and Heat.* — Germs cannot stand a very high temperature. Boiling water will kill most germs in a short time. For this reason the bedding and clothing of a person who has a germ disease such as diphtheria, typhoid fever, measles, tuberculosis, etc. should be washed in boiling water and hung to dry in the wind and sunlight. The germs in milk can be killed by boiling it or by pasteurizing it. To pasteurize milk, heat it to from  $140^{\circ}$  to  $150^{\circ}$  F. for about thirty minutes, then place it in closed vessels to prevent other germs from entering. Many of the diseases of children can be avoided by using pasteurized milk.

Dishes used by diseased persons can be made harmless by leaving them in almost boiling water for a few minutes. Foods that are well cooked or baked are thoroughly sterilized. But germs may get into such foods after they are cold, by being handled and hauled through the streets for delivery, as is done with bread and other baked articles. The receptacles for canned goods should be placed in the sunshine for several days and washed in boiling water just before using. Boiling the food for canning usually kills all bacteria, yeast, and mold that may be in it. If it is placed in the jars while hot and then

sealed, no destructive organisms can get into it, and it will keep for a year or more. Mold grows little seeds called *spores*, and yeast and bacteria can form a protective covering over the tiny body cell. It may take an hour or more of boiling to kill these, and if any of them are on the food to be canned they will not be killed by the few



INSIDE OF PASTEURIZING APPARATUS FOR MILK

The milk is heated by running steam through the coil. After thirty minutes the milk is cooled by causing ice water to flow through the coil.

minutes of boiling. They will start to grow in the sealed can or jar and cause the food to spoil and sometimes burst the can open.

When wounds or sores are full of dangerous disease germs, physicians kill them by applying a very hot piece of metal—a tool made for the purpose. A strong

caustic may also be used. This method of sterilizing is called *cauterization*. The hot iron is the *cauter*.

(B) *Germs and Chemicals.* — Besides sunshine, heat, and air, man has learned to use a great number of chemical compounds to fight his tiny enemies, the germs, which are always ready to attack him at every opportunity. More persons are killed in the fight with germs than in all other wars, even if man does employ many weapons. Some of the common disinfectants, or substances which will kill germs, are: lime (unslaked), chloride of lime, carbolic acid, sulphur, formalin or formaldehyde, mercuric chloride or corrosive sublimate. Most of these are rank poisons and must be used with care and caution.

Air-slaked lime is of no value as a disinfectant, for it will not kill germs. Lime slaked in water forms the caustic lime which will destroy decaying matter as well as bacteria. It can be used as a whitewash for barns, animal pens, and outhouses, and when put on by a spray pump will find the germs in all the cracks and corners. As it is very cheap it can be used to disinfect wet places and outhouses by scattering it about on the ground. Carbolic acid can easily be mixed with the whitewash, making it destructive to lice and other insects.

*Chloride of lime* is a comparatively cheap disinfectant because a small quantity can be made effective over a very large area. A few pounds in a large street-sprinkling tank will kill all the germs in the dust touched by the water while sprinkling. It is also very effective in garbage cans and water-closets. It has a strong odor of chlorine, for chlorine gas is liberated when the chloride of lime, or bleaching powder, is acted on by mild acids or when it is exposed to the air. It destroys disease germs by indirect oxidation.

*Carbolic acid* is a strong poison and must be used with care. It can be mixed with water for washing out cupboards and mopping floors during house-cleaning. Three or four drops in a teaspoonful of water may be used for washing lingering sores on animals or man. When mixed with vaseline it is good for killing germs in sores.

*Sulphur* is easy to use, but not very effective. It will not kill bacteria in the spore form, that is, in the form in which they are dry like dust and lie in the cracks and corners or float about in the air. The sulphur dioxide formed by burning sulphur requires the presence of moisture to kill germs. To fumigate a room or building with sulphur, close all openings as tightly as possible. Place in the middle of the room a large vessel with a few inches of water in the bottom, and in the center place a couple of bricks on edge so that they extend out of the water. Put a pound or two of powdered sulphur in an iron vessel and set it on these bricks. Place a piece of paper soaked in alcohol or oil down into the sulphur, allowing the end to extend out above the sulphur. Now open all the closets and drawers in the room and light the paper, leave the room, and close the door. After several hours the room can be opened and aired. Do not use the room until the sulphur smell is gone.

*Formaldehyde* is a very dangerous poison, but is one of the most powerful disinfectants. It is used by barbers, dentists, and physicians for disinfecting tools and instruments. The tools may be dipped into a weak solution or laid in a closed case filled with formalin gas or vapor. It may be used in water-closets and sick-rooms. Formaldehyde candles are used to fumigate sick-rooms in much the same way as sulphur.

For personal disinfection soap and water will remove

the dirt and germs but will not kill them. One should always wash before eating. Before performing an operation, physicians wash their hands and dip their instruments into hot water or a solution of formalin and then into boiling water. Since hydrogen peroxide liberates oxygen readily, it makes a good personal disinfectant.

(C) *Chemicals as Preservatives.* — In the section on Germs and Heat we learned that food, sealed up air-tight after the bacteria, mold, and yeast had been killed by boiling, would keep for a long time, the principle being to keep these tiny plants out of the food after those in it have been killed. In the section on Germs and Chemicals we learned that these germs could be killed by certain compounds as well as by the use of heat and sunshine.

These chemical compounds that will kill germs used to be employed very extensively in dilute form in foods. When the bacteria fell into these foods they died, and hence the food would not decay or sour. This was cheaper than canning. But it was a serious menace to health, and no one could long endure the constant use of such poisonous preservatives. So national laws have been enacted prohibiting such a practice and requiring the manufacturers to indicate on the labels the quantity and kind of chemicals used, if any. These laws do not prevent all the wrong use of chemical preservatives. There are always some people who will violate law, so each person should be more or less on his own guard by learning the facts.

*Borax* and *boric acid* are used on meats and will restore tainted meats to the appearance of freshness. Tainted meats are often made into sausage which is treated with chemicals. Benzoate of soda is used in catchup. Cheap

candies are often dipped in varnish to prevent the action of the air. Formalin is sometimes put into milk to prevent souring. No food so treated is good to eat.

The best and most harmless chemical preservatives are those discovered long ago. They are common salt, vinegar, spices, and wood smoke which is used for preserving meat. Spices, however, should be used sparingly.

Wood is protected by such compounds as *varnish* and *paint*. Linseed and poppy-seed oils are the best. Turpentine is used to make the paint dry rapidly. Iron and lead oxides are used, but the lead paints are the best if used with good linseed oil. The oil is a preservative, and the thin coat of lead and dried oil on the surface prevents water and air from entering the wood. Railroad ties and street paving-blocks are soaked in an oily solution of *creosote*. Creosote is a poison and so prevents the growth of any organisms in the wood. Iron and other metals when exposed to the air and moisture are oxidized and form rust. This is prevented by covering them with lead paint or coal tar. The coal tar is used on bridges made of steel, as it is a very cheap preservative.

#### **QUESTIONS AND EXERCISES**

1. Examine all kinds of wooden posts and determine where they decay most rapidly. Explain. How can decay be prevented?
2. Make a list of the diseases in your community caused by germs. What remedies are used for some of them?
3. Name some good disinfectants and tell how to use them.
4. Moisten a small piece of bread, roll it a yard or more on the floor, keep it moist and at room temperature for three or four days, and observe what happens. Explain.
5. Are your parents careful about the kind of preserved foods which they buy? Why?

## CHAPTER VI

### HABIT-FORMING AGENTS

26. Dr. Harvey W. Wiley, formerly chief agricultural chemist of the United States, is an authority on the subject of *habit-forming agents*. He said: "Either through neglect, carelessness, or consent of parents and teachers, thousands of school children are becoming addicted to drug habits. . . . In addition to these drugs, many children are allowed to drink *tea and coffee*, and thus take into their systems an *alkaloid, caffein*, which has the tendency to take away the sense of fatigue, stimulate the heart's action, and, in general, to urge the child forward to greater physical and mental activity than he should be called upon to endure. In the normal child the brain and body give timely notice of fatigue; in the abnormal child, fed partly on tea and coffee, these danger signals are struck down, and the child has no sense either of physical or mental fatigue. Thus he keeps on working when, if nature had her way, he should be resting. Physicians and teachers should combine to urge upon parents the desirability of not allowing school children to use tea or coffee.

"In addition to these drugs containing caffein there are about a hundred *so-called soft drinks* on the market of the country, sold under different names, to which caffein has been added so as to make the beverage, when consumed, have about the same quantity of caffein that

tea and coffee contain. Coca Cola is a type of these beverages, and it is sold near schoolhouses in hundreds of the cities of this country. To what extent the children patronize these caffeinated drinks cannot be determined accurately, but that they do patronize them is well known. Teachers and parents should join in their efforts to prevent children of school age from indulging in these very threatening beverages. They are of a character, as the phrase runs, to get on your nerves, and should be rigidly excluded."

**27. Stimulants.** — Stimulants are drugs that increase heart and nervous activity, and relieve the sense of fatigue. A person can easily be overworked under the influence of a stimulant because the tired feeling cannot appear. Because of this fact many children do not grow as they should and therefore become stunted for life, both in mind and body. Proper rest is just as necessary as exercise and should be taken when the sense of fatigue comes. Fatigue is the signal given by the nervous system for rest. If this signal is broken down by the use of stimulants, a wrecked life can be expected and the extent of the wreck will depend on the kind and amount of stimulant used. There are times when stimulants are necessary to save lives, but at such times the persons are sick or have suffered from some accident. *Stimulants should be taken only under the direction of a competent physician.*

The three common stimulants are *tea*, *coffee*, and *cocoa*. They all contain the stimulants known as *alkaloids*. Tea contains *caffeine* or *theine*. Coffee contains *caffeine*. Cocoa contains *theobromine*. The effects produced by these three are very similar. The ordinary drinks made from tea, coffee, and cocoa contain from one to two

per cent of the alkaloids. But in these small amounts it is well known that they greatly affect the nervous system.

Tea and coffee have practically no food value, but cocoa contains some nutritious fats and carbohydrates (starch and sugar) and so cocoa is the least harmful of the three. But enough fats and carbohydrates can be obtained from foods in which there is no stimulant.

**28. Narcotics.** — Narcotics are drugs which deaden the nerve sense and usually hinder proper *heart* action. In large doses they cause sleep. In any quantity, how-

ever small, they weaken brain and muscular energy. For this reason they should never be taken except when given by a competent physician. The three common narcotics are *nicotine*, *alcohol*, and *opium* in its various forms. Boys contracting the drug habit usually follow these up in the order named.

*Nicotine.* — Nicotine ( $C_{10}H_{14}N_2$ ) is the narcotic found in tobacco. It is a colorless liquid

and is such a strong poison that one drop of it will kill a dog. Nicotine boils at a temperature of  $476^{\circ}$  F. ( $247^{\circ}$  C) and during the burning of the tobacco in smoking the heat turns the nicotine into steam or vapor and it is then drawn into the mouth, sometimes into the lungs, and a part of it blown out through the nose. As soon as the smoke gets into the mouth or lungs its temperature is lowered and the nicotine soon condenses into the liquid form and is then absorbed by the blood. Nicotine is the poison



TOBACCO PLANT

which makes boys sick the first time they use tobacco. Cigarettes are usually made of poor tobacco dipped in a solution of nicotine and other narcotics, often some form of opium. These additional narcotics in cigarettes are as harmful to the users of them as the nicotine.

Smokers in high school and college rank on the average from 10 per cent to 25 per cent lower in their studies than the non-smokers. In college the percentage of smokers who take athletic honors and scholarships is lower than that of non-smokers. "As a rule, the non-smoker is mentally superior to both the occasional and the habitual smoker." (Edwin C. Clarke.)

Alcohol is made by the yeast plant. The process is known as fermentation. Alcohol is in all fermented and distilled liquors and is the active principle that causes intoxication or drunkenness. Distilled liquors or whiskeys are made by distilling fermented grains and fruits. They contain from 40 per cent to 60 per cent of alcohol. Fermented drinks are made by allowing various fruit juices to ferment. They contain from 5 per cent to 14 per cent of alcohol. Sometimes alcohol is added to wines and so they may contain 25 per cent of alcohol. Malt liquors, such as beer, are made by allowing yeast to ferment barley mixed with hops. They contain from 3 per cent to 5 per cent of alcohol. The per cent of alcohol in root beer, usually a homemade drink, depends on the amount of yeast used and the time permitted for fermentation. Many of these drinks, sold by the saloons and sent out by the distillers to the consumers, are adulterated with narcotics which are more injurious than alcohol itself.

The best physicians of the world have said that alcohol is a narcotic poison even in the smallest amounts and

therefore should be dealt with as other poisons and its general sale prohibited.

*Opium and Other Narcotics.* — The various forms in which opium is used are: morphine ( $C_{17}H_{19}O_3N$ ), codeine ( $C_{18}H_{21}NO_3$ ), narcotine ( $C_{22}H_{23}O_7N$ ), and heroin.



OPIUM POPPY

Laudanum is a mixture of opium and alcohol. Most of the opium fiends use opium in the form of morphine. Codeine and morphine are used in some patent cough remedies and soothing sirups. Cocaine ( $C_{17}H_{21}O_4N$ ) is taken from coca leaves and is used to relieve pain.

#### 29. Patent Medicines. —

The kinds of patent medicines on the market are numerous and nearly all contain alcohol.

Many of them contain more alcohol than do strong wines, while some have as much as poor whiskey. They are advertised for every kind of petty ill, but they only benumb the nerves, thus making the danger greater instead of effecting a cure. Some persons who would not think of taking beer, wine, whiskey, or any other intoxicating drink consume patent medicines containing large quantities of alcohol and thus thoughtlessly expose themselves to mental and physical danger. In case of any physical disorder, serious accident, or disease, the family physician should be consulted.

**30. Headache Powders.** — On account of carelessness in the habits of exercise, rest, and eating, a great number of ills, of varying degrees of severity, are developed.

Headache is one which is a frequent but unwelcome visitor. The sufferer usually tries to get rid of it as soon as possible and in any way possible, and will resort to drugs from time to time instead of attempting to remove the cause by living a hygienic life. For such careless persons there are on the market several drugged headache powders, which contain acetanilid, acetphenetidin, antipyrin, caffeine, etc. These compounds are habit-forming drugs and should never be used. Codeine and morphine are also used in some powders. These remedies in general simply benumb or stupefy the senses, and do not remove the cause of the trouble.

**31. Cold and Cough Remedies.** — Colds and coughs are among the most common ailments of children, and many special mixtures have been prepared and placed on the market for treating them. These remedies usually contain one or more habit-forming drugs, and some contain ether and chloroform. Such remedies as these should not be permitted in the hands of the general public, as effective cough and cold medicines can easily be prepared without the use of such drugs.

**32. Soothing Sirups.** — A host of drugs have been prepared for all the ills of early childhood. Careless mothers give these remedies to their children without much or any hesitation. As soon as the effects of one dose pass away, the child becomes irritable and fretful. Another dose is administered, the craving is met, and the child is quieted. This is a condition which is similar in every respect to the drug habit among grown people.

The remedy for the use of such drugs—habit-forming agents—is education and their removal from the market.

**QUESTIONS AND EXERCISES**

1. Make a list of all of the "soft drinks" of which you know. Which contain caffeine or other drugs, and which do not?
2. Enumerate all of the good results derived from the use of soft drinks.
3. Enumerate all of the bad results derived from the use of soft drinks.
4. Now compare the two lists of results. What is your conclusion?
5. Determine how much money you spend every year for soft drinks. Is it wisely spent?
6. Observe whether children who use tea or coffee are as healthy and have as pleasant dispositions as those who do not use tea or coffee.
7. Observe whether tea and coffee affect the health and "temper" of parents.
8. Consult some good physiology for the effects of stimulants on children.
9. Notice what effects narcotics, such as tobacco, alcohol, opium, etc. have upon those who use them.
10. Is the man who uses alcoholic drinks as good a home-maker as other men?
11. Make a list of "patent medicines," sold in drug stores, that contain one or more narcotics. What do you think about the use of such medicines?

## CHAPTER VII

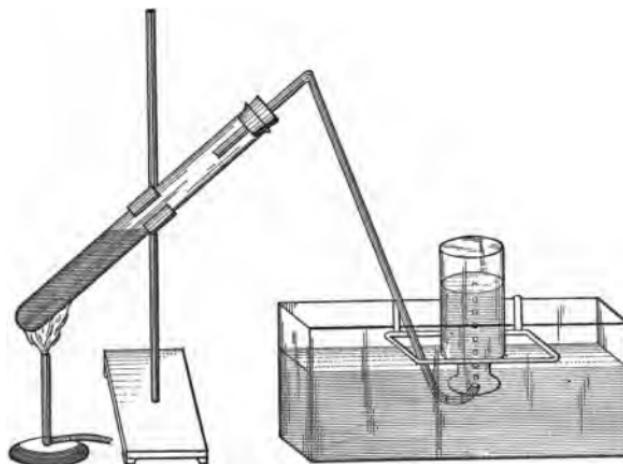
### OXYGEN AND OXIDATION

**33. The Air** which we try to keep pure in our room and which we breathe is composed of several gases which are thoroughly mixed. These gases are *nitrogen*, *oxygen*, *carbon dioxide*, and a few others which are not so useful to man. Evaporated water is in the air in varying amounts and is very necessary for health. A person cannot study well in a room where the air is too dry. *How can we keep the air from getting too dry for health?*

The three important gases that make up about 99 per cent of the air do not vary much in amount. Each one is always present in about the same per cent where the air is unconfined and free to move about as wind. *Nitrogen* composes about 79 per cent of the air, and its use, as far as oxidation is concerned, is to dilute the oxygen and prevent too rapid burning. *Carbon dioxide* composes about .03 per cent of the air and is formed by burning coal, gas, or wood. *Oxygen*, which composes about 20 per cent of the air, is the gas that is necessary in the process of burning and of breathing.

**34. Preparation of Oxygen.**—Weigh out about six grams of *potassium chlorate* ( $KClO_3$ ) and the same amount of *manganese dioxide* ( $MnO_2$ ). Mix these two compounds in powdered form on paper and place the mixture in a test tube. Have the test tube perfectly dry inside and outside. Close the test tube by a rubber

stopper with a glass tube through it as shown in the illustration, letting the other end of the glass tube extend under the mouth of a bottle on the shelf in the pneumatic trough. Fill several large-mouthed bottles with water, cover with a glass plate, and invert them on the shelf of the pneumatic trough over a hole; then remove the glass plate. With a Bunsen burner held in the hand,



PREPARING OXYGEN

By heating a mixture of equal amounts of potassium chlorate and manganese dioxide.

apply heat to the test tube very carefully; see that the flame does not stay in one place, and that the entire end of the test tube containing the compounds is equally heated, or the test tube may be broken and then all the oxygen will escape without going into the bottle. The first gas that comes from the test tube through the delivery tube is air and should be allowed to escape before placing the end of the delivery tube under the inverted bottle. As the bottles are filled with gas the water will flow out because of its own weight. When a bottle is

filled with oxygen gas it can be removed from the shelf by slipping a glass plate under its mouth while still in the water; it can then be placed on the desk in an upright position. Leave the bottle covered to prevent any possible mixture of the oxygen with the air. This will permit the filling of as many bottles as desired. To prevent the breaking of the test tube, remove the delivery tube from the water before you take the flame away from the test tube. Why?

*Properties of Oxygen Gas.*—Put into a bottle of oxygen gas a splinter of wood with a glowing spark on the end, and note the result. (1) Oxygen supports combustion or burning. (2) It will stay in the upright uncovered bottle, and will flow out if the bottle is inverted; hence it is heavier than air. (3) It is tasteless, colorless, and odorless. Try it and see.

**35. Oxidation.**—Oxidation is a process in which the atoms of oxygen unite with the atoms of other substances to form new compounds. Oxidation liberates a great amount of heat. The heat energy necessary to draw trains, drive automobiles, keep our houses and bodies warm, all comes from the burning of carbon or carbon compounds. When oxidation occurs so rapidly that a flame is produced, it is commonly called burning, as coal or gas burns in a stove or furnace.

We saw in § 34 that oxygen supports combustion or burning. The great quantity of oxygen in the air is one source of its supply. The earth itself is composed of about 45 per cent of oxygen. With all of the great fires that we have in factories, in machines, and in buildings to produce heat energy, the per cent of oxygen and carbon dioxide of the out-door air does not change much. The reason for this is that plants use carbon dioxide and liberate oxygen

when they make starch. Since oxygen in large amounts is necessary for burning, fires will not burn well when they do not get enough air to supply the oxygen. In most gas lamps the gas is mixed with air before it flows to the part where it burns. This insures more perfect oxidation of the gas and hence a better light. A current of air is allowed to flow into the fire of a furnace to supply oxygen. The gas that comes from a fire or gas lamp has a large per cent of carbon dioxide.

**36. Kindling Point and Spontaneous Combustion.** — The kindling point of a substance is that temperature at which the substance will begin to burn in a flame. Various substances have a different kindling point, and the smaller the amount of the substance, the easier it is to raise its temperature to that point. For this reason when we want to start a wood or coal fire we place shavings at the bottom and on these fine kindling wood and then heavier wood, and finally on top of all this material we place larger pieces of wood or coal. The burning match will raise the temperature of the shavings to the burning or kindling point, and they in turn will heat the kindling wood, and so on up to the kindling temperature of the largest wood or coal. When wood or coal is heated to the kindling point a gas escapes, and the burning of this gas is what makes the flame. Sometimes hay in a barn or old rags and paper stored in sheds or closets, become so hot that the kindling temperature is reached, and the whole building containing the material will burst into flame; this is called *spontaneous combustion*.

The ancient method of raising wood to the kindling temperature was by friction, that is, by rubbing two sticks together till they caught fire. The American Indians used this method. Then came into use the

flint-stone and steel, by which a spark was made to fly on fine kindling material called "tinder." During the Colonial days of America fire was also carried in earthen buckets from house to house. During the second quarter of the nineteenth century the first form of our modern match came into use.

### 37. Friction Matches.—

Matches are made to be used in the same general way as the ancient method of making fire by friction. The difference is that the match is made of material with a low kindling temperature. One stroke of the match on the proper surface will produce enough heat to raise it to the kindling point and so it burns into a flame. The match is made of pine, dipped in oil, and then into a mixture of phosphorus, sulphur, and glue. The phosphorus has a low kindling point and is held on the match-wood by the glue. The common matches were made of yellow phosphorus. This will catch fire in the air at a temperature of 95° F. That is why the matches smoke when held between the fingers. Yellow phosphorus is also extremely poisonous. Because matches made of this phosphorus are dangerous, the safety matches are very widely used. Some are made of red phosphorus, which will not burn till heated to 500° F. The safety match-head commonly contains a mixture of potassium chlorate, potassium bichromate, powdered glass, and glue or dextrine sugar. The friction surface on the box is made of a mixture of red phosphorus, antimony sulphide, manganese dioxide, and glue. The powdered glass is used to produce more friction and thus make



TINDER BOX, FLINT, AND STEEL

it easier to raise the temperature of the match to the kindling point. Safety matches can be lighted only on the prepared surface of the containing box or on plates of glass like window panes. They were first made in Swdeen.

38. When any substance unites with oxygen the process is called *oxidation*. This may occur very slowly and at a low temperature, as the rust on iron is formed by oxygen uniting with the iron, producing an iron oxide. Most metals will unite with oxygen to form oxides, but not so rapidly as iron. In all kinds of animal life oxidation takes place, and the heat evolved produces the energy that enables the animals to move about. An animal could not move if oxidation should stop in its body. There are many one-celled, microscopic animals and plants which live by eating larger dead animals and plants, producing what is commonly called decay. The one-celled animals and plants take in oxygen and give off carbon dioxide, and so when they eat up other animals and plants the process which we think of as decay is really oxidation. When carbon or its compounds are oxidized, a gas is formed which is known as carbon dioxide.

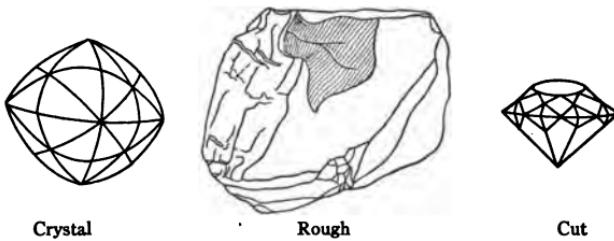
#### QUESTIONS AND EXERCISES

1. Make a collection of various kinds of matches. Which can most easily be lighted? Why will some light if you step on them and others will not?
2. Why will damp hay in a barn sometimes ignite?
3. What may happen if you store away a large pile of rags, some of them oily ones? Why?
4. What material would you use to start a wood or coal fire? How would you arrange the material?
5. What use is made of a large part of the food which we eat?

## CHAPTER VIII

### CARBON DIOXIDE

**39. Carbon and its Forms.** — Carbon is a simple substance or element composed of simple molecules. It exists in forms varying from powdered charcoal to the hard crystallized form known as diamond. It enters



DIAMONDS.—A FORM OF CARBON

into the composition of all plants and animals, being one of the most important elements. Our bodies—the bones and flesh—are partly carbon, and the smallest microscopic animals contain carbon. A large percentage of the plants around us, such as the grass, flowers, vegetables, and trees contain carbon. It is in the wood, oil, coal, and gas that we burn, in the clothes we wear, in the food we eat. We are kept warm by the oxidation of the carbon in the food we eat. Buildings are heated by oxidizing the carbon in the fuel.

*Charcoal* is one of the commercial forms of almost pure carbon, and it has many uses other than for fuel. Some is used in the reduction of ores and purification of metals.

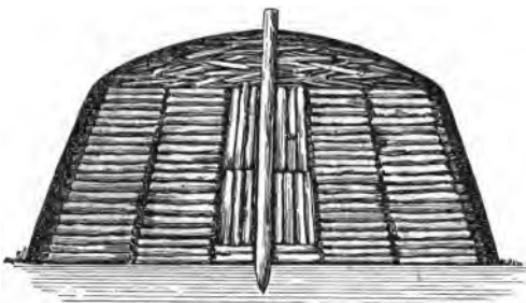
It is also widely used as a filter for purification of air, water, sugar, vinegar, etc.

Sewer gases, which have a bad odor and are sometimes poisonous, can be prevented from escaping to the streets and buildings by the use of charcoal filters at the sewer exits. As charcoal is very porous, it absorbs the poisons of the gases and thus keeps the regions surrounding sewers clean and free from bad odors. Pieces of charcoal placed in flower vases will prevent discoloration of the water and absorb the odorous gases of the stems that may be decaying. Charcoal filters used to purify drinking water may become dangerous, as the pores of the charcoal may become filled with impurities, and thus as more water flows through, it may become contaminated instead of purified. Such filters should be changed or cleaned often. It is very difficult to wash the filth out of the filter unless the charcoal is in powdered form. The charcoal may be purified by heating it to redness. This will oxidize all the dangerous material collected in the pores.

*Sugar* is made of the sap from the sugar maple tree and of the juice from the sugar cane and the sugar beet. The raw liquids from these plants are boiled down, that is, the water is made to evaporate, and the sugar is allowed to crystallize. This is known as raw sugar; it has a brown color and usually an unpleasant taste. This raw sugar is sent to the sugar refinery, where it is heated and again turned into a sirup. The sirup is filtered through charcoal known as bone black or animal charcoal. From this filtered sirup the white, clean sugars on the market are made. The charcoal made from animals has a greater refining power than that made from wood, and for this reason it is used in the sugar industry,

*Charcoal* and *Coke* are made on the same principle, namely, by heating coal, wood, or bones in an oven or any place to which air does not have free access. This prevents enough oxygen from getting to the burning substance to permit complete or perfect oxidation. But the heat produced will nevertheless drive out the water and some gases and leave the coke and charcoal.

Wood charcoal used to be made by cutting the wood in lengths of about four or five feet and then making a



WOOD ARRANGED FOR BURNING INTO CHARCOAL

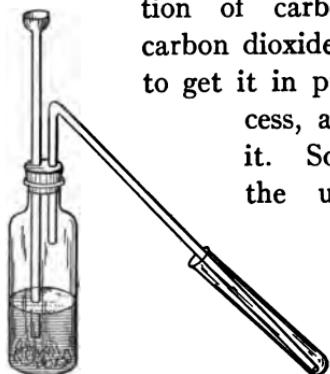
stack of this by standing it on end and covering it with earth about a foot deep. An opening was left at the top for the gases to escape. It was permitted to burn for a day or two and then the fire was put out by closing all openings by which air could enter or smoke escape. This would extinguish the fire, because burning cannot continue without oxygen and the escape of carbon dioxide. After the fire was out the earth covering was removed and the wood charcoal was ready for market.

A large percentage of the soft coal mined in Pennsylvania and neighboring states is made into coke. Long double rows of brick coke-ovens are made and filled with coal. An opening about one foot in diameter is left at

the top, through which the gas of the burning coal can escape. While the coal is burning a large flame of fire can be seen at this opening. After the gas has been driven out of the coal and burned, a large hole is made in the side of the oven and the coke is taken out for shipment.

**40. Preparation of Carbon Dioxide.** — Carbon dioxide ( $\text{CO}_2$ ) is composed of the two simple elements, carbon and oxygen. One atom of carbon and two of oxygen make the molecule of carbon dioxide. Whenever the oxida-

tion of carbon or its compounds occurs, carbon dioxide is formed. It is very difficult to get it in pure form by any oxidizing process, as other gases are mixed with it. So we shall have to resort to the use of compounds containing carbon and oxygen in the proper combination to be liberated in the form of carbon dioxide ( $\text{CO}_2$ ).



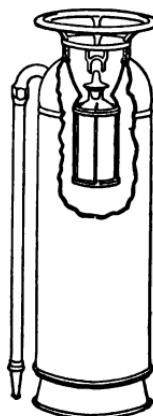
**MAKING CARBON DIOXIDE**  
By pouring hydrochloric acid on marble chips.

If baking powder is placed in water or baking soda in vinegar, carbon dioxide will be liberated. If marble, limestone, or chalk is placed in dilute hydrochloric acid (HCl), carbon dioxide will be evolved. To collect the effervescing gas, place the marble in a large test tube or a bottle, close it with a rubber cork containing a thistle tube and a delivery tube. Have the delivery tube bent and long enough to extend to the bottom of a test tube or bottle as shown in the illustration. Now pour a little hydrochloric acid into the thistle tube, and the carbon dioxide will pass out through the delivery tube into

the collecting bottle. As the carbon dioxide is a little heavier than the air at the same temperature, it will force the air out of the bottle and will itself stay in as long as the bottle is in an upright position. Can you see, taste, or smell carbon dioxide? Carbon dioxide is not poisonous, but if it is breathed in sufficient quantity it will cause death by keeping oxygen out of the lungs.

**41. Uses of Carbon Dioxide.** — Some natural spring waters are charged with carbon dioxide and are called carbonated waters, such as are found at Colorado Springs. Soda water is charged with carbon dioxide. The most valuable commercial use of carbon dioxide is in the fire extinguisher, various forms of which are on the market. The fire extinguisher used by fire companies and known as the "chemical wagon," and smaller ones for hand use are made of a strong metal case containing a saturated solution of bicarbonate of soda (baking soda) and a glass bottle full of strong sulphuric acid. The bottle is held rigidly in place, but the stopper fits loosely.

As long as the extinguisher is in an upright position the acid stays in the bottle and no gas is produced, as the two compounds cannot mix. When the extinguisher is inverted, the acid escapes from the bottle into the soda solution; chemical action then takes place and carbon dioxide gas is set free. The gas produces great pressure in the extinguisher and forces the solution out. This carbonated solution is directed at the base of the fire by a nozzle. Carbon dioxide does not support combustion,



PORTABLE FIRE  
EXTINGUISHER  
(Partly Open)  
Showing Stopper-  
ed Acid Bottle in  
Original Position.

and it keeps the oxygen of the air away, so the fire dies because it cannot get sufficient oxygen to make it burn. The liquid also helps to lower the temperature of the burning material below the kindling point, thus giving the extinguisher or "chemical wagon" a double effect. It is only used, however, when the fire is small or is just starting. The way water extinguishes fire is by cooling the burning material below the kindling temperature, and the steam that is formed keeps the air away.

The carbon dioxide which comes from the breath of all animals and from fires used for heating, lighting, and power production would soon make the air unfit for us to breathe if it were not for a natural provision for the consumption of this gas. Nearly all plants have the power to make starch out of water and carbon dioxide, when they grow in the presence of sunlight. This starch is used by the plant to make heat and wood fiber or the body of the plant. When the plants make starch they give off pure oxygen. So the plants use what the animals give off as waste and the animals use what the plants give off as waste.

#### QUESTIONS AND EXERCISES

1. Examine some hard and soft coal and charcoal. What differences do you find? Of what are they chiefly composed?
2. Name all of the things produced when carbon is oxidized. Which one is most useful?
3. What effect has carbon dioxide upon fire? Why?
4. What effect has water upon fire? Why?
5. What commercial uses are made of carbon dioxide?
6. What causes bread dough to rise?

## CHAPTER IX

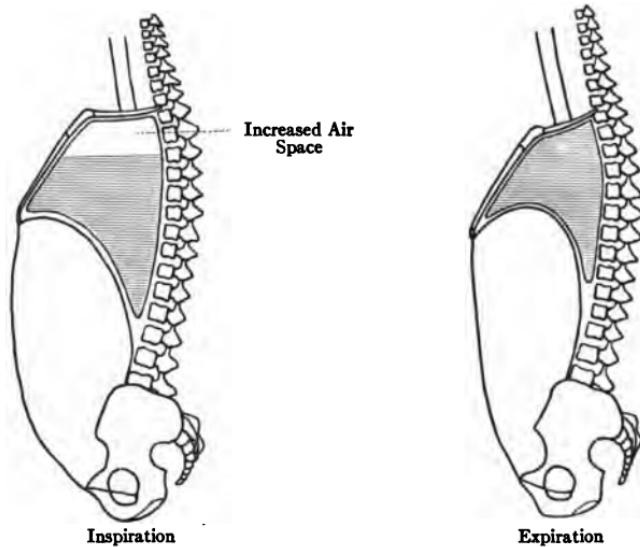
### BREATHING AND VENTILATION

**42. Breathing.** — From the chapter on Oxidation we learned that a fire is kept burning by a continuous supply of air which contains oxygen, and that the oxidation of carbon compounds produces heat. Our bodies are kept warm by oxidizing the food that we eat. The energy necessary to move and to do work is produced in our bodies by oxidation. In order to live, this oxidizing process must never stop. It is the fire of life, and when it stops life itself ceases. The body has two organs, the lungs, whose work it is to get oxygen into the blood for distribution to all parts of the body.

Breathing, then, consists of the process of allowing the air to flow into the lungs and forcing it out again. By the action of the muscles of the chest and the diaphragm, the chest cavity containing the lungs is enlarged and the air flows in because the pressure of the air on the outside is greater than the pressure of the air in the lungs. Air always flows to the place where the pressure is least. When the lungs are full of air, the muscles of the chest contract and force the air out. The air flows out because the pressure in the lungs is then greater than the pressure of the air on the outside.

Lamps do not burn brightly or fires abundantly if the supply of oxygen is for any cause insufficient. So it is with our bodies. We shall not be bright and happy and

able to work and play unless we keep a continual supply of pure air flowing into our lungs. The lungs must also be kept healthy and open so that the oxygen may pass into the blood. To insure this the muscles of the chest and the diaphragm must be developed and made strong by breathing exercises. The lower part of the



DIAGRAMMATIC SECTIONS OF THE BODY IN INSPIRATION AND EXPIRATION

chest should not be made smaller by tight clothing such as ladies sometimes wear. In this way serious ill health is often caused in later life. The evil results of tight bands worn about the waist, especially by young girls, frequently continue to make the life of the victim miserable to its end.

**43. Mouth Breathing.** — We sometimes see children and adults continuously breathing through the partially open mouth. Notice yourselves to see if you are doing this. The mouth was not made for the purpose of taking air into the lungs, but the nose was. People

breathe through the mouth from one or more of the following causes: (1) They may have abnormal spongy growths in the back part of the nose. These are called *adenoids*. They keep the air from going through the nose, and so the child who has them is compelled to open its mouth to get air. In addition, adenoids interfere with the flow of blood to the brain and cause indistinct pronunciation of words, listlessness, inattention, poor memory, partial deafness, and frequent colds, or earache. The signs indicating the presence of adenoids are parted lips, prominent eyeballs, a narrow, high-arched roof of the mouth, and nasal speech. Adenoids can easily be removed by a physician. (2) Colds and catarrh cause the nose to be clogged by the slimy fluid secreted by the mucous membrane, so the air cannot easily pass through. (3) Carelessness and indifference on the part of many are also causes of mouth breathing.



ADENOIDS

They swell and obstruct breathing.

**44. Effects of Mouth Breathing.** — (a) The mouth passage is much shorter for the flow of air than by way of the nose, so the air breathed through the mouth is not warmed before reaching the throat and lungs and hence irritates the vocal cords and causes coughing, and finally a husky voice will result. In cool weather colds may result from mouth breathing. (b) The mouth does not strain out the dust and germs as the hairs and mucous folds in the nose do, and so the throat and lungs become irritated and diseases may be contracted from the inhaled germs. The dust in the lungs will also hinder the flow

of oxygen into the blood and the flow of carbon dioxide out of the blood. It also makes the lungs less able to resist disease. (c) Mouth breathing causes a narrowing of the upper jawbone and the teeth may protrude forward and not have enough space for healthy growth. This in later life will cause the person to have continually an open mouth. (d) Mouth breathing causes improper enunciation of words and a harsh tone due to injured vocal cords. A mouth breather can never have a good voice for singing.

**45. Nose Breathing.** — (a) By inhaling through the nose the air is warmed and irritation of the throat and lungs is prevented. (b) Most of the dust and germs are taken out of the air before it reaches a place where injury might be done. (c) The air is moistened and so the throat is not irritated by dryness. (d) Colds are not so easily caught as by mouth breathing. (e) It permits the proper development of the face and avoids other evils of mouth breathing.

Deep breathing exercises should be practiced daily to cause the air to go to every part of the lungs and keep them open and also to develop the breathing muscles. Boys should never smoke, because tobacco smoke contains two dangerous poisons, namely, *nicotine* and carbon monoxide, which affect the whole air passage by irritating the mucous membrane, besides getting these poisons into the blood.

**46. Ventilation.** — Ventilation consists of keeping in our homes and buildings a supply of pure air for breathing. When it goes into our lungs, the air if pure contains about 20 per cent of oxygen and about .03 per cent of carbon dioxide. When it comes out of the lungs it is impure air and contains about 16 per cent of oxygen and 4.03 per

cent of carbon dioxide. Gas-lights and open fires consume much oxygen and give off carbon dioxide. To remove the carbon dioxide produced by breathing and by lights and fires, and to keep a continuous supply of oxygen, it is necessary to have openings for the air to enter our rooms. Each person should have about 300 cubic feet of fresh air every hour. Gas-lights and fires need more. In an ordinary-sized room of a home 10,000 cubic feet of air can be allowed to enter each hour without danger of a draft. Air must move three or more feet per second before it can be felt as a draft. If air is moving three feet per second through an opening with an area of one square foot, 10,800 cubic feet of air would enter each hour. Where there is no system of ventilation in a building, the windows should be lowered from the top, or the lower sash raised and a board placed under it so that the air will have to come in between the two sashes, thus giving it an upward direction. The windows of sleeping rooms should be kept open when they are occupied.



WINDOW VEN-  
TILATION WITH-  
OUT DRAFTS

#### QUESTIONS AND EXERCISES

1. Compare the chest and shape of the shoulders of those who take breathing exercises and those who do not.
2. Observe those who breathe through the mouth and see how it affects their appearance.
3. What should be done if children are found breathing through the mouth?
4. Who is more liable to get dust and disease germs into his lungs, one who breathes through the mouth or through the nose?
5. How do you ventilate your home? Your sleeping room?

## CHAPTER X

### MATTER AND ENERGY

**47. Matter.**—Matter or material is that which we think of as having weight or mass. Such materials as wood, rock, iron, books, water, air, etc. are what we think of as *matter*. From previous chapters we have learned that substances may undergo a number of changes.

For instance, the interaction of a base and an acid brought about a change (§13) by which both base and acid were destroyed, but the *material* composing them was not destroyed. The weight of the salt and water formed by the action of hydrochloric acid on caustic soda (§13) is the same as the combined weights of the acid and the base used. When coal is burned the combined weight of the carbon dioxide and other gases formed and the ashes left is the same as the combined weight of the coal and oxygen used to burn it. We can take a board and cut it into pieces and make a box of it, and the weight of the box will be the same as that of the board less the weight of the sawdust and the pieces wasted.

We have seen many kinds of transformations of matter, but in no case was it destroyed. Its use to man may have been destroyed, but not the material; as when a wagon is wrecked, its usefulness is gone, but the material of which the wagon was made still exists. From our experiences with matter we could say that matter cannot be destroyed, but its form and appearance can be changed.

We also might add that matter cannot be created by man. If you think it can be created, make some salt, or carbon dioxide, or a chair, without taking any material out of which to make it. We can change the form of matter, but we cannot create or destroy it. The law of the conservation of matter is: *Matter cannot be destroyed or created, but can be transformed.*

**48. States of Matter.**—There are three forms or states in which matter exists, namely, solids, liquids, and gases. The molecules of which all material is composed are moving rapidly, and they are never perfectly at rest.

When matter is in the form called a solid, as ice and iron are at ordinary temperatures, the molecules are held within a given space by the force of attraction which they have for one another. They cannot move enough to change the shape of the solid, commonly speaking.

When the molecules are made active by the application of sufficient heat, their speed becomes so great that much of the force of attraction which they have for one another is overcome; then the molecules of matter form what is known as a liquid. In liquids the molecules move over or about one another with such speed and ease that the liquid will take the shape of the vessel containing it. The reason that liquids can be poured from one vessel to another is because of the ease with which the molecules move.

If sufficient heat is applied to matter in the liquid state, the molecules become so active and move about with such speed that the force of attraction which they have for one another is completely overcome, and they continue to bounce about like a tennis ball batted by two players. Matter in this state is called a gas. Any quantity

of gas placed in a closed vessel will take the shape of the vessel and also *fill* it, because the molecules move in every direction with great speed. It is the continuous hammering of these millions of molecules on the sides of the containing vessel that produces what is known as gas pressure. The pressure due to the molecules of a gas hitting the sides of the vessel or gas pipe could be illustrated by letting a stream of small lead shot fall on a balance scales. It would be found that the force of the stream of shot would be proportional to the number of shot striking the balance per second, if their speed is kept constant, which could be done by permitting them to fall from the same height. The pressure of a gas is proportional to the number of molecules striking the sides of the containing vessel per second, if their speed is kept constant. Their speed is dependent upon their temperature.

From the chapter on Chemistry of Common Things we learned that all matter is composed of molecules. Complex molecules are composed of two or more atoms. Atoms are composed of *electrons* or ions. By great scientists, such as Professors Millikan and J. J. Thompson, it has been found that the electron is only a charge of electricity, and when the electric charge is removed no weight is left. Hence atoms are composed of a number (varying from 700 in hydrogen to 160,000 in radium) of electrical charges so arranged that they are not easily moved out of their sphere of activity. Atoms compose molecules, and hence molecules are composed of charges of electricity. *All matter is composed of molecules; therefore, matter is electricity.*

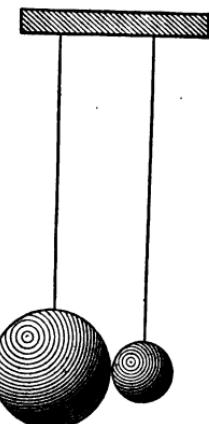
**49. Gravity.** — Gravity is the force with which the earth draws objects toward its center or holds objects

on its surface. This force is what gives objects weight; it causes objects to fall toward the earth. When a ball is thrown up, gravity stops it and draws it back to the earth's surface. It was Sir Isaac Newton who first explained why unattached objects fall.

The earth's attraction can be illustrated by the use of a magnet and an iron nail. A magnet is a piece of steel with its molecules so arranged that it can draw small pieces of iron to itself, and yet there is no kind of connection between the magnet and the piece of iron. When the nail touches the magnet it will adhere to the magnet much as an object is held to the earth by gravity.

All bodies — the sun, moon, stars, and even apples, balls, and stones — have the power of attracting other bodies toward them. This general force of attraction which bodies have for one another is called *gravitation*. Gravitation can be illustrated by suspending with long strings a large lead ball near a small brass ball. The brass ball will be drawn aside from a vertical position, or the distance between the strings near the balls will be found to be less than it is at the point of suspension. Gravitation is a property of matter, and it is the force of gravitation which holds the earth and all the other heavenly bodies in position.

**50. Energy.** — We cannot think of redness or beauty apart from some object or without having some object for their cause. So it is with energy. We cannot think of it except in connection with some material thing. So we define it thus: *The energy of a body is its capacity*



Two BALLS

Suspended near each other will show the influence of gravitation.

*for doing work.* Energy exists in various forms, according to the kind of body in which it is found, such as heat energy, mechanical energy, electrical energy.

Heat energy can be changed to mechanical energy, and mechanical to electrical energy, and electrical energy can be changed back to mechanical energy and heat. When fuel is burned in the cylinder of a gas engine the energy that the fuel contains is transformed, part appearing in the form of mechanical energy which does work, and a considerable part taking the form of heat. If the engine is run without pulling a load, all the energy of the fuel used is changed into heat, in part directly in the cylinder and in part through the heating of the bearings by friction. Such an engine is spoken of as a transformer of energy because it changes one form of energy into another.

The process in our bodies is similar to that in the engine. The materials digested from our food are carried by the blood to the working tissues and there virtually burned. Part of the energy may be used to do visible external work, but even then much of it is converted into the form of heat. While our bodies are in a state of so-called rest, the work done by the internal organs finally results in the generation of heat, somewhat as does the motion of the engine when it is not pulling a load.

In a great number of investigations it has been found that whenever one form of energy disappears an equivalent amount appears in some other form. Thus, if heat is produced by mechanical means, such as the fall of an object from a height, friction, or other means, the heat which appears is always exactly proportional to the mechanical energy used in producing it. If the stored-up energy of gasoline is used to run an engine, the work

done plus the heat produced always bears the same relation to the energy contained in the gasoline burned. When heat is used to make water hot, the water will give out as much heat on cooling as it took up in becoming heated. The heat required to change water to steam is given out when the steam is condensed. This principle is used in steam-heating plants.

This universal experience is expressed in the law of the conservation of energy, which may be stated thus: *Energy can neither be created nor destroyed, but it can be transformed.* It may change its form, but its total amount is neither increased nor diminished.

If coal is burned in a locomotive, it makes heat which changes water into steam, and the steam moves the locomotive and cars. This is one of the ways of making use of the energy stored in coal. If the coal were burned in a wrecked locomotive it would produce heat just the same, but the heat would be wasted as far as man's immediate use is concerned. So the law of the conservation of energy does not mean that energy cannot be wasted. It is man's business to use his energy and all kinds of energy effectively — to use it where it will bring valuable results.

#### QUESTIONS AND EXERCISES

1. Examine several kinds of substances and note any differences.
2. What are the three states in which matter can exist?
3. Do all substances in the liquid state have the same temperature?
4. In which of the three states are the following most useful: water, iron, silver, mercury, sugar, gasoline, coal?
5. What holds objects on the earth?

## GENERAL SCIENCE

6. What makes the water flow in creeks and rivers?
7. What causes wagons, electric cars, and sleds to run down hill easily?
8. Why is it difficult to draw a heavy wagon up a hill?
9. As far as you know from experience, does the law of the conservation of energy seem to be true?
10. Which requires more energy, to walk on the level or up a hill? Why?

## CHAPTER XI

### **HEAT**

**51.** Heat is a form of energy which causes all molecular activity. It can be produced by the chemical action known as oxidation. Since energy cannot exist apart from matter, heat cannot be thought of except as a condition of matter. The faster the molecules of a substance move the more heat it contains. A piece of iron which is red-hot has more heat in it than when it can be held in the hand. The molecules of the iron are also more active when it is red-hot.

Heat is made in our homes by burning wood, gas, or coal. When coal is burned in boilers, the heat generated changes water into steam. When gasoline is burned in the engine of an automobile, it generates enough mechanical energy to drive the machine at high speed. Heat generated by fires is used to melt ores and for the forging of iron. Heat is used to prepare our meals, to make our homes comfortable. It enables plants and animals to grow and thus produce our food. By the oxidation of the food in our bodies we are kept warm and able to move about. All of us have daily experiences with heat in some form. Because of this close relation to daily life it is important that every one should know a few facts and laws concerning heat. Every one should know how to use the instruments for measuring the degree of heat of a body and something about the relative amount of heat that given substances will absorb.

**52. Thermometers.**—The thermometer is an instrument used to measure the degree to which a body is heated, that is, to determine its temperature. We sometimes use our fingers or even our whole bodies to measure temperature. We often put a finger into water or on objects to see if they are hot or cold. If their temperature is higher than that of our finger we say they are hot. If the temperature of the object is lower than that of our finger we say it is cool or cold. When we go from one room to another we say that the rooms are of the same or of different temperature, according to our feeling. Our sensation of temperature is largely determined by the condition of our bodies as regards health, and by the moisture conditions of the surface of our bodies and of the air. For example,  $70^{\circ}$  F. in January would be a hot day, while  $70^{\circ}$  F. in July would be a cool day. Moist air in winter seems cold and dry air seems warmer. In summer dry air is cool and moist air is hot to our feeling, while the actual temperature on the day when the air is moist may be the same as when it is dry. For the above reasons our bodies do not make very good thermometers. Neither can we determine very accurately the temperature of water or any object with our fingers.

Certain substances have been found to be very sensitive to changes of temperature, and these have been used to construct mechanical thermometers, of which there are three principal types. Only two will be considered here. They are the *Fahrenheit* and the *Centigrade thermometers*. The Centigrade thermometer is the easier of the two to use, as its scale is based upon the decimal system.

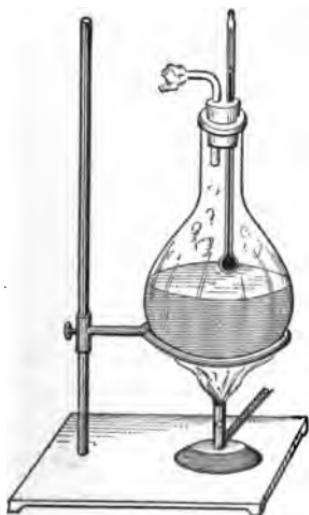
**53. How to make a Thermometer.**—Take a glass tube about 12 inches long, with a very fine hole at one end and extending through to a closed bulb at the other end.

Slowly heat it to a very high temperature to drive out all moisture. Slip a cork tube over the open end and have the cork tube tight on the glass and extending about a half inch above the end of the glass tube. Fasten the tube securely on a ring-stand in a vertical position and fill the cork cup at the top almost full of mercury. Slowly heat the bulb at the bottom to drive out some of the air by expansion. After a few air bubbles escape through the mercury, allow the bulb to cool and the mercury will flow down as the air contracts while it is cooling. After the mercury stops flowing down heat the bulb again as before, and then let it cool. Continue this process

until the bulb and tube are both full of mercury and all the air out.

Take the thermometer tube, now full of mercury, and slip it through one of the two holes of a rubber stopper and put it into a flask containing some water. Do not let the bulb touch the water. Put a tube into the other hole of the rubber stopper to direct the escaping steam away from the thermometer, and heat the water to the boiling point.

THERMOM-  
ETER  
TUBE



HOW TO LOCATE THE BOILING POINT

After the mercury in the tube ceases to flow out, seal the top by directing a gas flame against it to

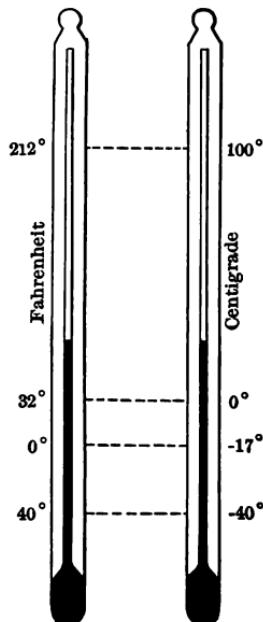
melt the glass, but at the same time keep the water boiling. While sealing the top more mercury will flow out because of additional expansion due to the high temperature of the flame. As the glass tube cools at the top after having been sealed, the mercury will contract somewhat. After it stops contracting mark the top of the mercury  $100^{\circ}$  for the Centigrade thermometer or  $212^{\circ}$  for the Fahrenheit.



HOW TO LOCATE  
THE FREEZING  
POINT

for Centigrade or  $32^{\circ}$  for Fahrenheit. This will be the freezing point.

To make a Centigrade thermometer, divide the distance between the two marks,  $0^{\circ}$  and  $100^{\circ}$ , into 100 equal parts. To make a Fahrenheit thermometer, divide the space between  $32^{\circ}$  and  $212^{\circ}$  into 180 equal parts. Now mark off spaces below  $32^{\circ}$  the same size as those above it. Do the same on the Centigrade scale. Five-ninths of a Centigrade degree is equal to one degree of the Fahrenheit scale. Why?



PRINCIPAL POINTS ON  
THE CENTIGRADE AND  
FAHRENHEIT THERMOM-  
ETERS

Mercury freezes at  $40^{\circ}$  below zero and boils at  $360^{\circ}$  Centigrade and so cannot be used for very low or very high temperatures. Hydrogen gas thermometers are used for extremely low and high temperatures.

**54. Uses of Thermometers.** — Thermometers can, of course, be used only to determine the temperature of a substance. To determine the temperature with a mercury thermometer is to compare the molecular activity of a substance with that of mercury. When the molecules of mercury become more active they need more room, and the mercury moves up the thermometer tube. The amount of this expansion can be read by the degree marks on the tube. The temperature of the air in the schoolroom is measured by a thermometer on the wall. What kind is it? What is the most comfortable temperature of the air for the schoolroom and home? Physicians determine the temperature of their patients by placing a very small thermometer under the tongue or in the arm pit. The temperature of a healthy person's body is about  $98.4^{\circ}$  F. If it rises very much above or falls below the normal temperature, there is something physically wrong with the individual.

In all kinds of manufacturing in which substances are heated, the approximate temperature must be known, and in most cases the exact temperature must be ascertained. The temperature of the ovens for baking is carefully watched; also the temperature of the syrup in sugar refineries; and especially is the temperature observed in the manufacture of fine steel for razors and watch springs. The purity of substances such as butter and olive oil can be determined by noticing their characteristics at a given temperature. Pure butter will

melt at about  $94^{\circ}$  F., and if butter does not melt at this temperature, it has impurities in it.

**55. Meaning of Temperature.**—*Temperature is only the degree to which a body is heated.* It is the relative condition of a body with respect to the degree of heat of other bodies. Suppose that a pint of water on the stove has a temperature of  $95^{\circ}$  C. and that a two gallon bucket full has a temperature of  $95^{\circ}$  C. Their relative condition, respecting temperature, is the same, but do they have the same amount of heat? Which quantity of water would get hot quicker, a pint or two gallons, on the same fire? Which would cool quicker after being taken off the fire? Which would melt the most ice if slowly poured on a 300-pound block? If the two gallons of water on the same fire heat more slowly than the pint of water, it must take more heat to raise the temperature of the two gallons to  $95^{\circ}$  C. than it does to raise the pint to the same temperature. If the two gallons of water cool more slowly than the pint under the same conditions, or if the two gallons melt more ice than the pint of water, then the two gallons must have had more heat than the pint of water when they were both at the temperature of  $95^{\circ}$  C.

A small room in winter can be heated to  $21^{\circ}$  C. in a short time with a small fire, but to heat a large room like an auditorium to  $21^{\circ}$  C., in winter, would require several hours with a large fire. Then which room will have the more heat in it when both are  $21^{\circ}$  C? Which one will feel the warmer? Which will take longer to cool if only one door is opened, the auditorium or the small room? Why?

From these two observations it can easily be seen that the temperatures of the two quantities of water and the

two rooms do not tell you how much heat there is in each, but only the comparative degree of heat. The temperature does help in finding the amount of heat in the water. The quantity of heat put into a gallon of water cannot be determined unless the temperature is known when the heat is applied and also when the water is removed from the fire. *But a degree of heat on the thermometer is not a unit of heat, it is a unit of temperature.* So we need to make use of another unit, the unit of heat.

**56. Calorie.** — The calorie is the unit of heat. *The calorie is the amount of heat necessary to change the temperature of one gram of water 1° C.*, or it is the quantity of heat given out by one gram of water when it cools 1° C. If 500 grams of water are heated from 5° C. to 25° C., the change in temperature is 20° C.;  $500 \times 20 = 10,000$ , the number of calories of heat taken up by the water. If 1,000 grams cool from 40° to 25°, the amount of heat given out is  $15 \times 1000$ , or 15,000 calories.

To measure the length of your desk you would use inches, to measure the length of the room you would use feet or yards, to measure across a state you would use miles. All are units of length but of different size. The reason for using large units to measure large quantities is to avoid such large numbers. So for measuring a large amount of heat we have the *great calorie* or *kilocalorie*. It is 1,000 times as large as the calorie, defined above. The great calorie is used in measuring the heat we get from foods and also the fuel value of foods for animals. In tables giving the fuel value of the various kinds of foods, the calorie used is the great calorie.

**57. Specific Heat.** — Since it requires more heat to change the temperature of a gram of water 1° C. than to make the same change in the same weight of any

other substance, except hydrogen gas (which is not convenient to work with), the amount of heat necessary to change the temperature of 1 gram of water  $1^{\circ}$  C. was taken as the unit of heat—the calorie. All ordinary substances require less than a calorie of heat to change the temperature of 1 gram  $1^{\circ}$  C. If a pound of iron and a pound of water (a pint) are placed on a hot stove or a gas fire, which will get too hot to hold in the hand, the quicker? The temperature of the iron will increase about nine times as fast as the temperature of the water. The temperature of a pound of mercury will increase 30 times as fast as that of a pound of water under the same conditions. That is, it takes 30 times as much heat to change the temperature of one gram of water  $1^{\circ}$  C. as it does to change the temperature of one gram of mercury  $1^{\circ}$  C.

Because of this variation in the amount of heat necessary to change the temperature of a gram of any substance  $1^{\circ}$  C. we have what is called specific heat. *The specific heat of a substance is the amount of heat needed to change the temperature of one gram of that substance  $1^{\circ}$  C.*, or it is the amount of heat given out when the temperature of one gram of that substance falls  $1^{\circ}$  C. in temperature. The specific heat of water is 1, of iron .11, of mercury .033, of copper .095, of lead .031. That is, it takes .11 of a calorie to change the temperature of 1 gram of iron  $1^{\circ}$  C., and .033 of a calorie to change the temperature of 1 gram of mercury  $1^{\circ}$  C.

**58. Sources of Heat.**—The chief natural source of the earth's heat is the sun. The rays of the sun warm the surface of the earth, and it in turn warms the air. The air does not absorb much heat directly from the sun's rays. It is the sun's heat that makes our summers warm and gives energy to the growing vegetation upon

which man and other animals are dependent for food. Some substances, as was shown in § 55, do not require as much heat to change their temperature as others. It was also shown that water per unit of weight requires more heat to change its temperature than any other substance except hydrogen, that is, its specific heat is greater than that of any other substance. So when in the sunshine dry ground gets warm quicker than moist earth, and the land gets warm faster than the water of lakes, rivers, and oceans. For this reason, land surrounded by water or near a body of water does not become very hot in summer, and is not so cold in winter. In winter the water is giving out the great quantity of heat which it absorbed during the summer and thus moderates the climate and prevents extreme cold weather. For this reason it is possible to grow large quantities of fruit along our Great Lakes.

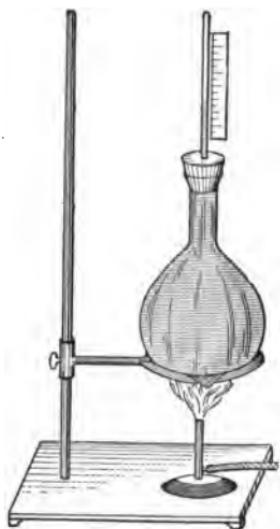
Other sources of heat are the chemical processes which man employs for heat production, such as burning wood, coal, gas, etc. These substances all contain carbon, and by the oxidation of carbon much heat is produced. The heat thus produced can be largely regulated by controlling the supply of fuel and the rate of oxidation. Without this means of producing heat civilization could not exist. Our homes would not be very happy places if in winter we had to eat sufficient food and wear enough clothing to keep our bodies warm without the aid of fire.

**59. Effects of Heat.**—In the chapter on Molecules and Atoms<sup>1</sup> we learned that as the molecules of a substance become more active they require more space and so crowd one another apart. Heat makes the molecules

<sup>1</sup> Chapter III.

more active, so when a substance is heated it will expand and occupy more space without its weight being increased. This can be illustrated by taking a flask completely full of water, closing it with a rubber stopper having a glass tube through it, and heating the water. As the water increases in temperature it will expand up the tube,

(if it was  $4^{\circ}$  C. or warmer at the start). If a substance will expand when heat is added, what will it do when heat is taken from it? Prove your answer by watching the water in the tube as the water in the flask cools.



SHOWING HOW WATER EXPANDS WHEN IT IS HEATED

water in the form of bubbles. More air can be made to escape by applying a Bunsen flame to the flask. Remove the heat and permit the flask to cool. The water will now flow up the tube into the flask, because the air in the flask contracts as it loses heat. A drop of ink can be made to flow up and down the tube by alternately heating and cooling the flask a few degrees.

A brass ball which will just slip through a brass ring when both are at ordinary room temperature will not pass through the ring when it is heated. If the ring is

heated to the same temperature as the ball, the ball will again pass through it. Why? What use does the blacksmith make of this same principle?

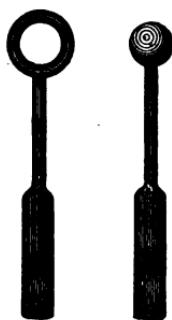
In summer the telegraph and telephone wires sag because of increase in length due to expansion. In winter they contract and are then stretched tight and produce the characteristic humming noise when the wind shakes them.

On a hot summer day the concrete walks will sometimes expand so much that they will crack or crumble. This is not usually noticed until cold weather when the concrete has



EFFECT OF HEAT ON AIR

As the air is heated it expands and escapes in the form of bubbles.



#### HEAT AND METALS

When the brass ball is heated it will not pass through the brass ring.

fallen from above because they were moved from their

contracted, leaving open spaces where it broke during the summer. In order to avoid much of the breaking of walks by the action of heat, expansion creases are put in about every three or four feet, when the walk is laid. The cracks between the ends of railroad rails also provide room for the linear expansion of the rails. When are these cracks between the railroad rails almost closed and when are they open? Why?

Along the base of rock cliffs there are quantities of small stones which have

position by expansion and contraction as the weather changed. For this reason it is often dangerous to walk along such places. Some rock may lose its equilibrium at any time and plunge to the bottom. The once barren, rocky plateaus of the western part of the United States have been so changed by the action of heat and water that it is now possible to cultivate them.

Water, unlike metals and rock, expands when it freezes and so assists in breaking up stones. It runs into the cracks of stones and freezes, breaking the stones apart and shoving the outer pieces off the cliff. It runs in between the grains of a rock, and when it freezes it causes the rock to expand so much that the rock crumbles and becomes fine earth after it thaws out again. In this way, in the temperate climates, the stones on the surface are being continually broken up. Even the bricks of a house are made to crumble by the freezing of the water in them. Paint will keep the water out of brick, and on this account it is used as a preservative.

In general, all substances — solids, liquids, and gases — expand when heat is applied to them, and they contract when heat is allowed to pass from them. Water, however, is an exception to this rule. Water is most dense at  $4^{\circ}$  C. That is, the molecules of water are closer together at  $4^{\circ}$  C. than they are at any other temperature, and hence a gram or pound of water will occupy less space at  $4^{\circ}$  C. than it will at any other temperature. If a gallon of water at  $4^{\circ}$  C. is heated, it will expand and require more space. If it is cooled below  $4^{\circ}$  C., it will expand. When water freezes it expands about one-ninth. Of what value is this property of water to man and to the animals that live in water?

**QUESTIONS AND EXERCISES**

1. State the uses made of heat that you have seen.
2. Does your body serve well as a thermometer? Why?
3. Why does the mercury of a thermometer rise in the tube when the air around it becomes warm?
4. What temperature on the Centigrade thermometer is the same as  $32^{\circ}$  F?  $98.4^{\circ}$  F?  $^{50}$  F?  $70^{\circ}$  F?  $-40^{\circ}$  F?  $212^{\circ}$  F?
5. Where do you have your thermometer at home? Is it of more use outside the house than in the living room? Why?
6. Explain the difference between temperature and calorie. Give the use of each.
7. Name the different ways of making heat. State some uses of heat.

## CHAPTER XII

### HEAT OF VAPORIZATION

60. When water in a vessel is placed on a stove, it can be made to escape by evaporation, and the faster heat is applied the faster it evaporates. The temperature of boiling water in an open vessel cannot be raised above the boiling point. The escaping steam carries the heat away as fast as the water receives it. When more heat is applied, the steam escapes faster and so carries off the extra amount of heat. The temperature of the steam is the same as that of the boiling water, but a gram of steam has more heat in it than a gram of water has. Since the temperature of the boiling water cannot be increased, and since the temperature of the steam coming from the boiling water is the same as the temperature of the water, a large amount of heat is required to change the water from a liquid into a gas or steam. *The number of calories of heat required to change one gram of a boiling liquid into steam is called the heat of vaporization of that liquid.* Since it takes about  $5\frac{1}{3}$  times as long completely to evaporate an open vessel of water as to raise it from  $0^{\circ}$  C. to  $100^{\circ}$  C., we conclude that the heat of vaporization of water at  $100^{\circ}$  C. is about 533 calories. Accurate experiments show that the heat of vaporization of water is 536 calories. Other liquids have a different number of calories for their heat of vaporization.

From Chapter X we learned that energy cannot be created or destroyed but can be transformed. The large amount of heat required to change water into

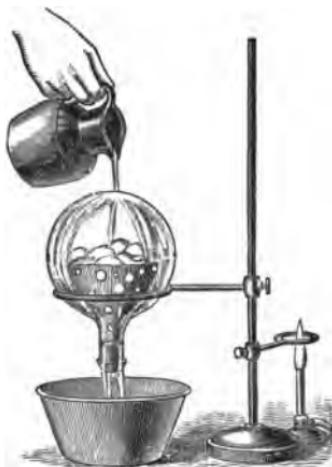
steam must be in the steam. This heat is given out again, or liberated, when the steam condenses and forms water. The heat of condensation is equal to the heat of vaporization. This can be proved by forcing steam into cold water. The water will rapidly increase in temperature. This is also illustrated by the steam-heating system. The steam comes into the radiators at a temperature of about  $100^{\circ}$  C., it condenses, and the water flows out at about the same temperature, but the room containing the radiator becomes warm. The heat comes from the steam condensing to form water.

**61. Boiling Temperature.** — When a liquid in an open vessel is heated, it will be found that there is a certain temperature above which it cannot be raised, no matter how fast the heat is applied. At this temperature bubbles of steam or vapor form at the bottom of the vessel and rise to the surface, increasing in size as they rise. The temperature at which this occurs is called the boiling temperature or boiling point. Boiling temperature may also be defined as the temperature at which the pressure of the steam in the steam bubbles in the liquid is equal to the pressure of the air or gas on the surface of the liquid. In an open vessel the pressure of the air on the liquid determines at what temperature the bubbles of steam will form in the liquid. So the pressure of the air determines at what temperature water will boil. At "standard pressure," which is about average air pressure at sea level, the boiling point of pure water is  $100^{\circ}$  C. If salt or sugar is dissolved in the water, it will not boil until it is heated above  $100^{\circ}$  C., depending upon the amount of salt or sugar put into the water. Try it.

Water on the top of a mountain will boil at a lower temperature than at sea level. Why? It will take

longer to cook potatoes on top of Pikes Peak than at Chicago. Why? In the city of Quito, Ecuador, water boils at  $90^{\circ}$  C., and on top of Mt. Blanc it boils at  $84^{\circ}$  C. At the Dead Sea water will not boil until its temperature is over  $100^{\circ}$  C. In a steam engine in which the pressure of the steam is 100 pounds per square inch on the surface of the water, the boiling point is  $155^{\circ}$  C.

The change of boiling point according to the pressure on the water can be illustrated by the following experiment.



#### CHANGING PRESSURE

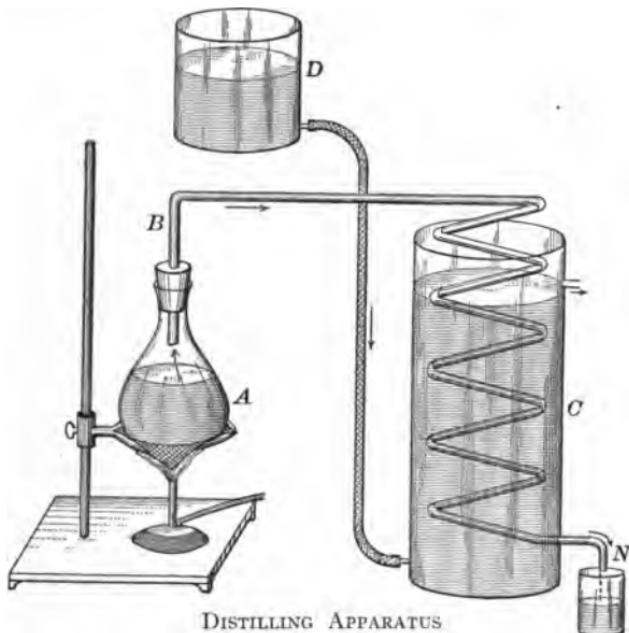
Showing how pressure influences  
boiling point.

Take a flask of about 400 cc. capacity. Fill it about half full of water and heat to the boiling point. While the water is still boiling, close the flask with a rubber stopper, being careful to remove it from the fire as soon as closed. Invert the flask on a ring-stand and pour over it some cold water. The cold water cools the glass and causes the steam inside to condense. This condensation reduces the pressure on the water in the flask, and the steam pressure in the

water becomes equal to the steam pressure on the water and so steam bubbles escape. The escaping of these bubbles is boiling. This cooling of the flask and the boiling of the water in it can be continued until the water can be made to boil by holding the flask in the hand. The author has made water boil in a flask when its temperature was  $19^{\circ}$  C., by placing ice on top of the flask.

Alcohol boils at  $78^{\circ}$  C., ether at  $35^{\circ}$  C., liquid air at  $-180^{\circ}$  C., and liquid carbon dioxide at  $-80^{\circ}$  C., at standard pressure.

**62. Distillation.** — Distillation is a process by which liquids are separated from one another or from salts dissolved in them, by first making the liquid evaporate rapidly by the application of heat and then condensing



DISTILLING APPARATUS

*A*, is the boiler; *C*, the condensing tank; *D*, the cold water tank; and *N*, the distilled water.

the vapor. The condensed steam or vapor is the distilled product. The substance to be distilled is placed in a closed vessel, *A*, having an outlet for the vapor through a tube, *B*. This tube passes through a cooling tank, *C*, through which cold water is kept flowing. As the vapor passes through the coils of the tube in the cooling tank, it is condensed and the pure liquid flows out at *N*.

When salts or other substances are in the water, the pure water can be separated from them by distillation, because the molecules of salt are too heavy to escape from the liquid with the vapor. "Hard" water, therefore, can be "softened" by distillation. Water for the manufacture of ice is also distilled. Large ocean vessels get pure drinking water for the passengers by distilling the salt water of the sea instead of by carrying a sufficient supply of drinking water from the port.

The commercial uses of distillation are very extensive. The sap of the long-leaf pine trees is collected in barrels and taken to a distillery for the manufacture of turpentine and rosin. When heat is applied the turpentine evaporates rapidly and comes out as the distilled product. The rosin, which is a residue of distillation, is left in the boiler, from which it is taken for the market.

In Chapter IV we learned that alcohol is a waste product of the yeast plant. Yeast cannot raise the quantity of alcohol in a liquid to more than 14 per cent. In order to get a high percentage of alcohol the process of distillation is used. The fermented fruit juices or fermented grains, such as corn or rye ground up and mixed with water and yeast, are distilled. Since pure alcohol boils at  $78^{\circ}$  C., it will evaporate much faster than water at  $78^{\circ}$  C., and so the vapor that comes from the fermented juices may contain from 40 to 60 per cent of alcohol, according to the per cent of alcohol in the fermented juice. This distilled product, containing from 40 to 60 per cent of alcohol, can be distilled again. The third time that it is distilled, almost pure alcohol is obtained. To this distilled product, containing 80 to 90 per cent of alcohol, quicklime is added. The lime unites with the water which is present in the mixture, but it does

not unite with the alcohol. The alcohol is then distilled again and is 95 to 98 per cent pure, and this is called absolute alcohol.

*Wood alcohol* is made by the dry distillation of wood. The wood is placed in an air-tight retort and heated. Wood alcohol is extremely poisonous, and when it is burned formaldehyde is produced, which is very hard on the eyes;  $\text{CH}_3\text{OH}$  (Methyl Alcohol) + O (Oxygen) =  $\text{HCOH}$  (Formaldehyde) +  $\text{H}_2\text{O}$  (Water). Some laboratory men have become blind by continuous use of wood alcohol as a heat producer.

The alcohols which are made by the yeast plant from grain or fruit juice and purified by distillation are also poisonous, but not so much so as wood alcohol. *As beverages, alcoholic liquids are recognized as neither necessary nor desirable for the best of health.* Many well-known physicians do not prescribe them for medicines.

*Denatured Alcohol* is grain alcohol made more poisonous by adding about 10 per cent of wood alcohol or other poisonous liquid, so that it cannot be used for beverage purposes.

**63. Fractional Distillation** is a process by means of which mixed substances, each having a different boiling point, are separated from one another. This is done by heating the mixture to the boiling point of each substance in succession and catching the condensed vapor in separate vessels. The many products of petroleum are obtained in this way. Rhigolene, which boils at a temperature of between  $20^{\circ}$  and  $25^{\circ}$  C., is the first to vaporize and pass off. This is followed by petroleum ether, boiling at between  $50^{\circ}$  and  $60^{\circ}$  C. Then comes gasoline, which boils at  $70^{\circ}$  to  $90^{\circ}$  C.; then naphtha, boiling at between  $90^{\circ}$  and  $120^{\circ}$  C.; followed by benzine, boiling at

between  $110^{\circ}$  and  $140^{\circ}$  C., and kerosene, which boils between  $150^{\circ}$  and  $300^{\circ}$  C. At still higher temperatures the heavy lubricating oils pass over, and lastly vaseline evaporates. Of the residue in the retort paraffine is made.

The manufacture of alcohol is also a form of fractional distillation. The first part of the distillate contains a higher percentage of alcohol than that which comes off later.

**64. Cooling by Evaporation.** — We have learned that when water in an open vessel is boiling, its temperature cannot be raised by applying more heat, because the increased heat applied is carried off by an increase in the rate of evaporation. That is, the water is kept cooled to  $100^{\circ}$  C., by evaporation. To cause water or any other liquid to evaporate requires heat. Water will evaporate at any temperature, but most rapidly at boiling point. If you cover your hand with water and then swing the hand it soon feels cool because heat is taken from the hand to make the water evaporate. In summer your body is kept cool by the evaporation of the sweat from the surface of the body. If it were not for this natural cooling process man could not live comfortably in hot climates. Most animals are kept cool in the same way. The evaporation of moisture from the leaves of plants keeps them cool and prevents the hot sun from scorching them. A heavy rain cools the ground and streets partially by evaporation. In cities the streets are sometimes sprinkled to cool them. Water can be made to freeze in summer by the rapid evaporation of ammonia or ether. When liquid carbon dioxide is allowed to escape from the containing cylinder, it evaporates so rapidly that a temperature of  $80^{\circ}$  C. below zero may be reached. Mercury can easily be frozen with the

frosty-looking carbon dioxide which comes from the cylinder.

Butter can be kept cool and solid by keeping moist cloths around it. This method is used extensively by good housewives in the country. Cheese and other foods can be kept cool in the same way with little expense and labor. Damp clothing should never be worn, because heat is taken from the body in order to evaporate the moisture in the clothing. If the clothing of any particular part of the body is wet, the evaporation may cool the body so much that the person will catch cold. Such conditions should be carefully guarded against.

After taking a bath the water should be at once removed from the body by the use of a rough towel to prevent the loss of heat by evaporation and to keep up a good circulation of the blood. In summer, when the air has about all the water vapor that it can hold, the sweat from the body does not evaporate fast enough to carry off the excess heat and so we become uncomfortably warm and say that the day is a sultry one. The sultriness is due to the lack of sufficient cooling by the evaporation of sweat.

#### QUESTIONS AND EXERCISES

1. Give practical uses made of the fact that vapors carry a large amount of heat.
2. Does water boil at  $100^{\circ}$  C. in your home? In your schoolroom? Why?
3. Name all of the distilled products that you have seen. State their uses.
4. How are the various products of petroleum obtained?
5. Does evaporation increase or decrease the temperature of the evaporating substance? What practical use is made of this?

## CHAPTER XIII

### HEAT OF FUSION AND DISSOLUTION

65. If water is placed over a fire, its temperature slowly rises until it reaches the boiling point. The heat then applied is used to change the water into steam. The temperature of the steam is the same as that of the water. What is the heat required to change water into steam called? If heat is taken from water its temperature will continue to decrease until it reaches the freezing point. Under ordinary conditions the temperature of liquid water cannot be lowered below the freezing point, or  $0^{\circ}$  C. If heat is taken from water at  $0^{\circ}$  C. it begins to freeze and change to a solid form. The temperature of the ice just frozen is the same as the water in which it is, that is,  $0^{\circ}$  C. A relatively large amount of heat is given out when a unit mass of water freezes.

If you want to change ice into water a relatively large quantity of heat will have to be applied just to make it melt, without changing its temperature. The temperature of the melting ice cannot be changed. It will remain  $0^{\circ}$  C. until all is melted. All the heat added is used to change it from a solid to a liquid form. The heat required to melt one gram of ice is the same as the amount of heat given out when one gram of water freezes. (What law does this suggest?)

66. **Heat of Fusion.** — *The heat of fusion of a substance is the number of calories of heat required to melt one gram of that substance without changing its temperature.* The amount of heat required to melt a substance is the same

as the heat given out when that substance freezes. So the heat of fusion is the same as the heat of solidification. The heat of fusion of ice is 80 calories. Every time one gram of water at  $0^{\circ}\text{ C.}$  freezes, it gives out 80 calories of heat without changing its temperature. This explains why water freezes so slowly and why ice melts slowly. After water is frozen, the temperature of the ice will decrease if the air around it is below  $0^{\circ}\text{C.}$  The specific heat of ice is .5, that is, when the temperature of one gram of ice is lowered  $1^{\circ}\text{ C.}$ , it gives out one-half calorie of heat.

Glass, unlike some other substances, does not change suddenly into a liquid. After it begins to melt it continues to increase in temperature if heat is added. The hotter it is made the easier it will flow. This is important in the manufacture of window panes, as it permits rolling the glass into thin sheets when in a semi-liquid condition.

**67.** When water freezes it expands about one-ninth. Nine gallons of water when frozen will become ten gallons of ice. The weight of nine gallons of water is the same as that of ten gallons of ice. Hence nine gallons of ice weigh less than nine gallons of water. Why does ice float on water? If a block of pure ice is placed in water what part of it will be above the water? Prove your answer by placing some ice in water.



BLOWING GLASS

Metals, as a rule, expand when they change from a solid to the liquid form and contract when they become a solid. Cast iron freezes at  $1200^{\circ}$  C., silver at  $954^{\circ}$  C., lead at  $330^{\circ}$  C., mercury at  $-39.5^{\circ}$  C. That is, these metals become solids at these temperatures. At what temperature do these same substances melt?

**68. Effects of Salts on Freezing.** — In freezing ice cream salt is mixed with the ice. The salt melts the ice. It requires heat to melt the ice and to dissolve the salt. The heat necessary to do this comes from the cream, and so its temperature is soon lowered to the freezing point. The application of ice and salt is continued until the cream is all frozen. When water has as much common salt dissolved in it as is possible, the solution will not freeze until its temperature is  $-22^{\circ}$  C. Why does ocean water not freeze as easily as river water?

If equal weights of ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ) and water at  $15^{\circ}$  C. are mixed, the temperature will decrease to  $-10^{\circ}$  C. If three parts of calcium chloride ( $\text{CaCl}_2$ ), in crystal form, are mixed with two parts of snow, a temperature as low as  $-55^{\circ}$  C. will result. This mixture will freeze mercury. These two salts are not used in making ice cream, because they are too expensive.

#### PROBLEMS

1. How much heat is required to change the temperature of 500 grams of ice at  $-20^{\circ}$  C. to  $0^{\circ}$  C? (Specific heat of ice is .5).
2. How much heat is required to change 500 grams of ice at  $0^{\circ}$  C. into water at  $0^{\circ}$  C? (Heat of fusion of ice is 80 calories).
3. How much heat is required to change 500 grams of water at  $0^{\circ}$  C. into steam at  $100^{\circ}$  C? (Heat of vaporization of water is 536 calories).
4. How much heat is required to change 100 grams of ice at  $-25^{\circ}$  C. into steam at  $100^{\circ}$  C?
5. If an iceberg in the form of a cube is 40 feet above the water, how far does it extend down into the water?

## CHAPTER XIV

### HEATING BUILDINGS

**69. Transmission of Heat.** — (a) *Radiation* is the process of transferring heat in straight lines through space without the aid of ordinary matter or material. All of us have had the common experience of standing near a hot stove or open fire in a grate, or near a steam or hot water radiator, and receiving the heat directly. If we stand near an open fire in a cool room, the part of the body toward the fire will be warm while the opposite side will feel cold. If two persons stand near an open fire one behind the other, the one in front next to the fire will receive the heat while the one behind will be cold. If an object is placed between us and the fire or radiator, the object reflects and absorbs the heat and we do not get any. If we stand in the shade of a tree in summer we do not feel the hot rays of the sun. All of these suggested experiences show that heat radiated from a hot object travels in straight lines, and many good authorities think that it travels as fast as light, namely 186,000 miles per second. The heat from the sun comes to the earth by radiation. Radiant heat passes through air without heating it, so the upper part of the atmosphere is cold. The lower atmosphere is heated by the air coming in contact with the surface of the earth and with things on it. We can get warm standing before an open fire even if the air is moving past us toward the fire, because the radiant

heat travels with such great speed through the air without heating it.

Glass will permit radiant heat to pass through it without itself being heated. For this reason the sun shining through the windows will warm a room. When the sun shines on a greenhouse the heat passes through the glass and makes it much warmer inside than the air is on the outside. Not much of the heat inside the greenhouse can pass out by radiation, as the objects are not hot enough to give off much radiant heat.

(b) *Conduction* is the process of transferring heat in an object by the activity of the molecules in the object itself or by two objects touching each other. We learned in Chapter XI that heat is a form of molecular activity. This molecular activity can be transmitted the entire length of an object or from one object to another if they are in contact. We have experienced the results of conduction by placing a spoon, knife, or fork in a hot substance and feeling the handle become warm; or by holding the end of an iron poker in the fire until the end in the hand became almost too hot to hold. How does the handle of a smoothing iron get hot? Why do we use a cloth on the handle of a smoothing iron?

The heat from the fire in a stove passes through the stove by conduction and keeps it almost as hot on the outside as it is on the inside. How does the heat pass from the stove into the room? The hot steam in a radiator makes the iron hot and the heat passes through the radiator by conduction, but it passes from the radiator into the room by radiation.

Silver is the best conductor of heat of any substance known. Iron conducts heat about one-eighth as easily as silver. Glass is a poor conductor of heat, only about

$\frac{1}{760}$  as good as iron. So glass prevents the escape of heat from a room but allows the radiant heat of the sun to pass through it. The conductivity of water is only about  $\frac{1}{200}$  of that of silver.

That water is a poor conductor of heat can be proved by taking a tall, narrow vessel, like a test tube, full of water and making the water on top boil while holding the bottom in the hand. The gas flame is applied only to the top of the vessel.

When heat is applied to the bottom of a vessel of water, the water on the top is heated by a process different from conduction. Any one who has been in bathing in a river or lake knows that the water is warmer on the top than it is several feet below the surface. Why?

Gases are the poorest conductors known, only  $\frac{1}{75}$  as good as water or  $\frac{1}{30,000}$  as good as silver. Air is a gas, and because gases are poor conductors of heat, the surface of the earth is not permitted to cool rapidly. Gases will transmit heat easily when they are free to move, but not by conduction.

The difference in the rate of conductivity can be experienced by placing the hand on a piece of iron and then on a piece of dry wood lying near. The iron will feel cooler than the wood in winter because it conducts the heat from the hand. (For this reason never touch your tongue or wet finger to a piece of iron during zero weather). The iron will feel warmer if both iron and wood are lying in hot sunshine, because the iron will



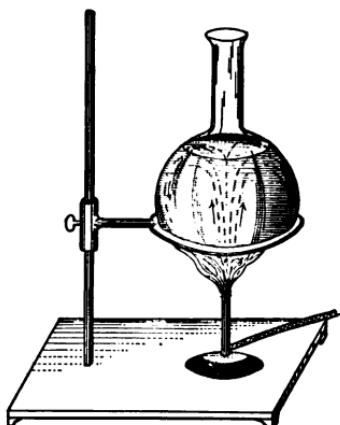
BORILING WATER  
In a test tube while holding it in the hand.

conduct its heat to the hand. The difference in the rate of conductivity of substances can be also experienced by stepping with bare feet from a woolen carpet on to an oilcloth in a cool room. Linen clothing is a better conductor of heat than woolen. At what time of the year should woolen and at what time should linen be worn? Why?

The influence that the air in the meshes of clothing has upon its power to conduct heat is very great. Felt, feathers, and fur make very warm coverings because they are very poor conductors of heat and thus prevent the escape of heat from the body. Their great number of minute spaces containing air or other gases helps to make them poor conductors of heat. Freshly fallen snow is a great protection to such crops as wheat, rye, and hay.

The roots of fruit trees are also protected by having snow on the ground during very cold weather, as the ground does not freeze very deep under the snow.

(c) *Convection* is the process of transferring heat by the flow of liquids or gases. This process can be illustrated by placing a few crystals of potassium permanganate in a flask almost full of clear water and then slowly heating it over a Bunsen burner. The coloring matter will soon reveal currents



CONVECTION CURRENTS

Showing currents while water is being heated.

of water moving around in the flask, going upward just above the flame and downward on the sides of the flask.

The coloring matter will be uniformly distributed in a very short time. These currents distribute the heat so thoroughly that the water in all parts of the flask is kept at about the same temperature.

The water nearest the flame becomes heated and expands. It is thus made less dense than the surrounding water, which forces the less dense water to the surface. While on the surface it cools a fraction of a degree and becomes more dense and so descends at the edge of the flask and forces the slightly warmer water up from the bottom. It can easily be seen how this method differs from conduction. *In convection the whole mass of molecules moves and warms others by contact, while in conduction the molecules heat their neighbors by a vibratory motion.*

This method of heat transfer is illustrated by the heating of buildings with hot air, steam, and hot water, and even to some extent by stoves or open fires. It is also illustrated by the ocean currents. The water in and near the Gulf of Mexico is heated by the sun, and this warm water, the Gulf Stream, moves across the Atlantic Ocean and warms the whole of Western Europe. The Japan Current coming across the Pacific Ocean warms our Western coast. These are two great natural heating plants. The convection currents of the ocean are partly caused by the unequal heating of the water by the sun.

Winds are also partially caused by unequal heating of the earth's surface, and therefore they are convection currents which distribute heat. When any part of the earth's surface is heated, the air over that part also becomes heated and so expands and becomes less dense, and hence it is not so heavy as the cooler air surrounding this heated area. This cooler air is soon flowing toward

this heated area; the cool air moves upward as fast as it is heated, thus carrying the heat away. The movement of the air in this case is something similar to the movement of the water in the flask in the illustration, but on a much larger scale. The winds and ocean currents are the great natural convection currents which distribute heat over the earth's surface.

**70. Primitive Methods of Heating.** — Man in his first steps toward civilization lived much like some of the savages to-day. He built his first fires out in the open as camp fires and warmed himself by them. He then built the same kind of a fire inside of the little hut that he learned to make. Over this fire primitive man also cooked his food. He gradually learned to build stones around the fire or around the place where the fire was to be built. Then to escape the evil of the smoke, he built a tall top to his stone firebox. This top was extended until it carried the smoke outside his little house. This stone firebox with its top to carry away the smoke finally developed into the open fireplace and chimney, such as the early settlers used in America. This type of open fire exists now in the form of the modern grate in which wood, coal, or gas is burned. Metal stoves and furnaces are modern inventions and very convenient in comparison with the ancient methods.

**71. Modern Method of Heating.** — Modern man tries to have the smoke and gases made by the fires carried from his home without poisoning the air in his living rooms. We to-day have several kinds of fuel which the ancients did not have. What are they?

There are four principal modern types of heating which will be discussed in the following four sections.

**72. The Open Fire and Stove.** — An open fire of

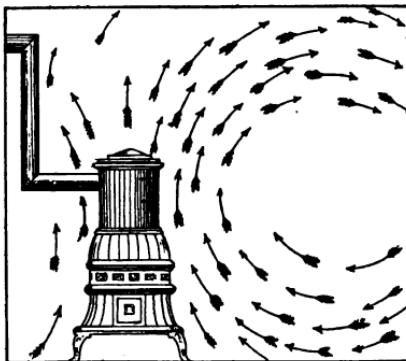
wood, coal, or gas heats the room by radiation. The floor, walls, and objects in the room are heated directly by radiation, and they in turn warm the air because the air comes in contact with them.

When stoves are used all three methods of heat transfer are brought into action.

The fire in the stove heats the iron. This heat is carried through the iron to the outside surface by conduction. A large part of the stove's heat passes to the objects in the room by radiation, and they in turn warm the air.

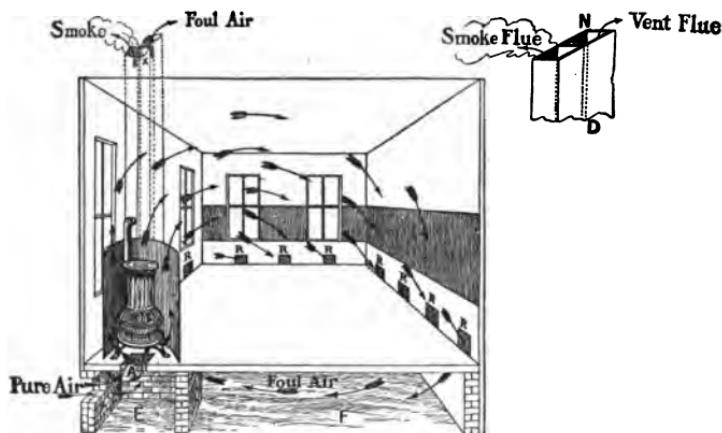
Much air also comes in contact with the hot stove and is heated by conduction. After it is heated it is forced upward rapidly by the cooler air coming toward the stove. So there is a continuous current of air rising over the stove toward the ceiling. It flows along the ceiling to the walls, where it is slightly cooled, and descends to the floor and goes to the stove again.

The illustration represents the heating of a schoolroom by the use of a stove. The fresh air from the outside goes through a duct to the base of the stove, where it is heated and forced to the upper parts of the room by the inflowing cold air. The warm air gradually cools and drops to the floor and moves through the impure air ducts. By this method the greater part of the room is heated by convection.



CIRCULATION OF AIR WITH A STOVE  
IN A SMALL ROOM

**73. Hot Air System.**—The hot air system is used extensively. Many public institutions use it by having a central heating plant and large hot air ducts leading to the various buildings. These ducts are placed underground and the air is forced through them by large fans

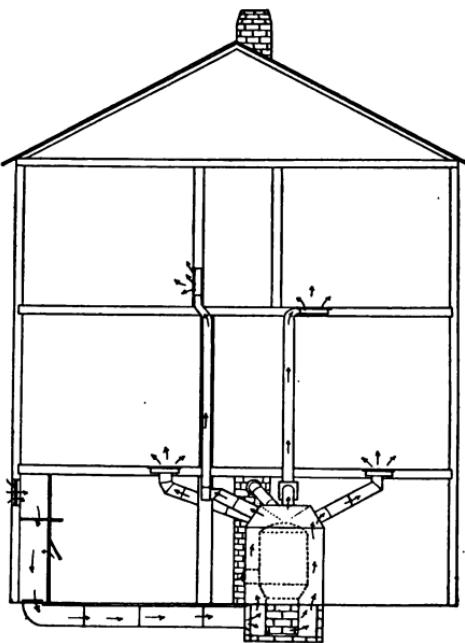


CIRCULATION OF AIR IN A SCHOOLROOM

The foundation enclosure, *F*, is made air-tight, with the only exit through the vent flue, *N*, in *D*. The enclosure, *E*, is shut off from *F*, but communicates with the outside air which passes through the register, *A*, over which is the heater. When a fire is started in the heater, the air around it rises and the outdoor air enters through *E*. At the same time the heat of the smoke warms the air in the vent flue through the partition, *X*, and creates an upward draft from under the floor. With these two drafts there is a continual circulation of the air in the room through *A* and the small registers, *R*, *R*, *R*, *R*, and up the vent flue.

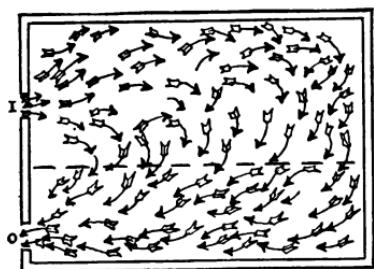
run by engines or motors. Fans are also used in large buildings where there is only one heating plant in the basement. Small private houses can be heated by this system without the use of a fan. The difference in the temperature of the air outside and that at the furnace in the basement is sufficient to insure the flow of air to the various rooms. The air outside the house is cold

and more dense than the hot air around the furnace, so it flows through the cold, fresh air duct to the furnace and forces the hot air through the hot air ducts to the rooms. The air keeps flowing as long as there is a fire in the furnace, and so the rooms are kept warm. In most private houses the air coming into the room from the furnace escapes from the room through the cracks around the windows and doors. This method provides for ventilation.



HEATING WITH A FURNACE — HOT AIR SYSTEM

In the school building in which the author teaches, the hot air system of heating is used. The fresh air coming from the outside passes through cloth screens to take out the dust. A large fan about twelve feet in diameter forces the air to the hot furnaces and from there into the rooms through openings near the ceiling at one corner. The rooms are warmed by convection currents.



SHOWING THE MOVEMENT OF AIR IN A SCHOOLROOM

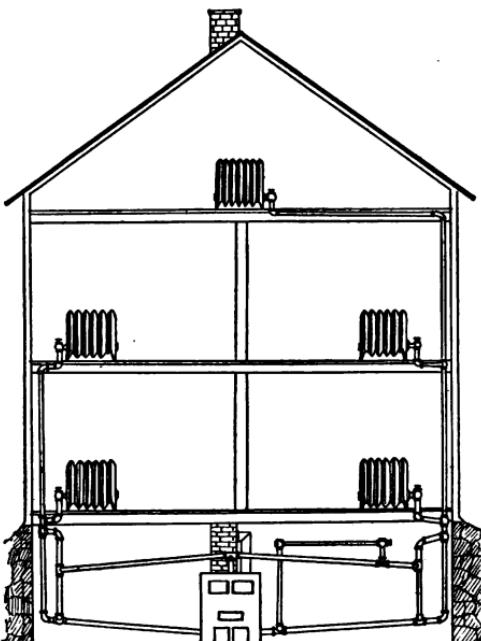
At the floor, just under the place where the hot air enters the rooms, is another opening for the cool and impure air to leave. It goes down through impure air ducts to another large fan, which forces it to the outside of the building, on the side opposite to that where the fresh air enters. The illustration shows the flow of air in one of the rooms. The air comes in at *I* and goes out at *O*.

**74. Steam Heating System.**—The steam system of heating is used extensively in large buildings and private houses. The apparatus consists of a steam boiler or boilers in the basement. The size and number of boilers depend upon the size of the building to be heated. The radiators in the rooms and halls contain a heating surface which is about one forty-fifth of the numerical cubic capacity of the rooms. The steam passes from the boilers to the radiators through pipes, and the condensed steam or water flows from the radiators through another set of pipes which lead to the bottom of the boilers.

The fire in the boiler changes the water to steam. The pressure of the steam, which is never more than a few pounds to the square inch, forces the steam from the boiler through the pipes to the radiators. The steam enters the radiators at a temperature of about  $100^{\circ}$  C. It condenses and the water flows from the radiator at about the same temperature. If this is true how does the room become warm from the radiator? After the steam is condensed it flows back to the boiler to be changed into steam again. So the water keeps up a continuous motion, flowing from the boiler to the radiators in the form of steam, and back to the boiler in the form of liquid. Is this conduction, convection, or radiation?

The flow of steam into the radiator is controlled by two valves on the radiator: one large valve lets the steam

into the radiator and also lets the condensed steam or water out of the radiator. Somewhere on the radiator, toward the opposite side or end from the large inlet valve, is a small valve which permits the air to escape when the steam is turned on and also lets in air so that the water can flow out of the radiator when there is no steam in the boiler. The small valve, if in good condition, closes automatically as soon as all the air is out of the radiator and the hot steam begins to escape. The valve opens again after it cools.



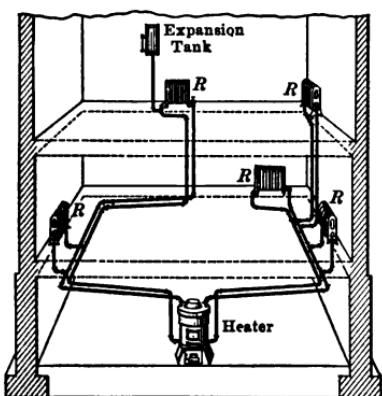
STEAM-HEATING SYSTEM

In this system the heat is carried from the boiler to the radiator by convection. The radiator is heated on the inside by conduction. The heat passes through the radiator by conduction. The heat passes into the room partly by radiation and partly by conduction. The air which touches the radiator is heated by conduction and so becomes less dense and is forced toward the ceiling by the cooler air moving toward the radiator. This process causes convection currents to be set up in the room and so the whole room is heated.

When the radiator is in the room, no provision is usually made by the heating system for ventilation as in the hot air system. The rooms have to be ventilated by opening the windows or by air ducts which permit air to enter under the radiators.

What is known as the hot air and steam system combined is sometimes used in large buildings. In this combination the steam radiators are placed in the basement and the cool, fresh air is forced over them and into the rooms by large fans and the impure air removed from the rooms by a fan, as in the hot air system. This is sometimes called the indirect system of heating.

**75. Hot Water System.**—The hot water system is very similar to the steam system except that the boiler in the basement and the radiators in the rooms and



HOT WATER HEATING SYSTEM

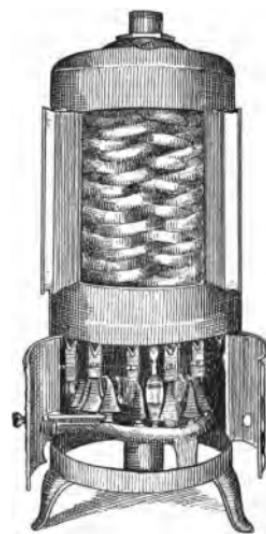
the pipes leading to them are all full of water, and a pipe extends to an expansion tank in the upper part of the house. This tank receives the overflow of water due to expansion by heating. There are pipes leading from the boiler in the basement to the radiators, and a system of pipes leading from the radiators in the rooms to the bottom

of the boiler in the basement, and through these the water flows from the radiators after it has cooled. In this system of heating all three methods of transfer of heat are used. The heat from the fire in the boiler is carried through the metal of the boiler by con-

duction and transmitted to the water in the boiler by conduction. The water next to the hot iron in the boiler, as it receives the heat expands, that is, becomes less dense, and is then forced upward by the cooler water at the bottom of the boiler, which is more dense. The supply of cool water is kept constant by the return from the radiators in the rooms.

This hot water is thus forced through the pipes from the boiler to the radiators and transmits its heat to the metal of the radiators by conduction. The heat passes off the radiator into the room partly by radiation, warming the objects in the room, and partly by conduction to the air which is touching the radiator. This air, as it is warmed, is forced toward the ceiling by the cooler air in the room flowing toward the radiator, where it in turn is heated and forced toward the ceiling; thus convection currents are set up in the air, which distribute the heat of the radiator to all parts of the room. The heat is transmitted from the boiler to the radiators in the rooms by the flow of the water. What method of transferring heat is this?

The hot water system of heating is one of the most economical that can be used in a private house. By this system the temperature of the house can be most easily controlled in the early fall and late spring. A small fire in the boiler will warm the water sufficiently



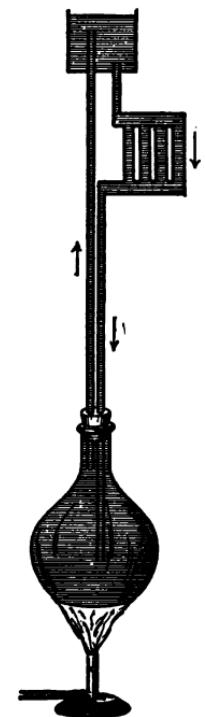
STEWART HEATER FOR  
HOT WATER SYSTEM  
Showing the copper coils in  
which the water is heated.

in the early fall, when not much heat is needed in the rooms, to cause the water to flow from the boiler to the radiators. The water thus flowing through the radiators is not very hot and will not give to the rooms an excess of heat like steam radiators. For example, the water

in the radiator may be at a temperature of only  $140^{\circ}$  F., and therefore not much heat will pass into the room, while in the steam system the radiator with steam in it has a temperature of  $212^{\circ}$  F., and hence will give off to the air in the room much more heat than is usually wanted.

The expansion tank in the upper part of the house is usually kept about half full of water. As the boiler and all the water pipes and radiators must be kept completely full of water, the water will have to have some open vessel into which the extra volume due to expansion by heating can flow, or else the radiators or pipes or boiler would burst when the water is heated. The expansion tank is usually connected with the outside of the house by an open pipe leading to a sink or to the roof. Through this pipe the water can flow if the expansion tank is too small to hold the extra volume of water due to expansion by heating.

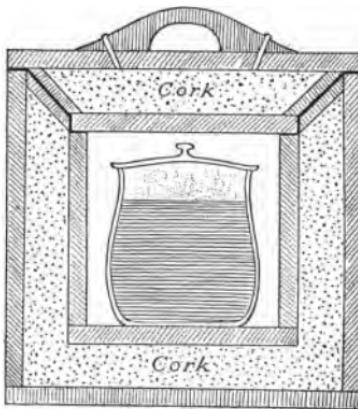
APPARATUS ILLUSTRATING THE HOT WATER SYSTEM OF HEATING



During extremely cold weather the boiler and the water pipes in the hot water system must be drained if no fire is kept in the boiler, in order to prevent the bursting of the pipes by freezing.

**76. Fireless Cooker.** — A fireless cooker may be made

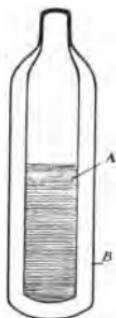
by taking a large box and putting into it about 6 inches of hay or sawdust or cork shavings and on top of this material setting another box of wood or paper of such a size that a space of about 6 inches will be left between the sides of the two boxes and also about 4 inches from the top of the inside box to the top of the outside box. The space between the two boxes should be filled with the same kind of packing material that was used in the bottom. The lid should fit the top of the large box and be about 4 inches thick with packing material between the upper and lower surfaces of the lid. When the vessel of boiling hot food is placed in the box and the lid closed, the heat cannot escape; the food to be cooked is thus kept at almost the same temperature as when it was placed in the fireless cooker. Hence, the food will cook the same as if left on the fire, but a little more slowly, because a small amount of heat will escape from the food to warm the inside of the fireless cooker.



FIRELESS COOKER  
Made of two boxes and cork packing.

The two walls of the fireless cooker, with the packing of sawdust or cork shavings between, enclose a great amount of air in the little spaces between the packing. Air, being a gas, is a very poor conductor of heat, and the packing prevents convection currents from being formed, and so the heat cannot pass from the inside of the cooker to the outside; thus the material is kept at the same temperature as when it was placed in the cooker.

It is not necessary to go to any great expense to enjoy the use and advantages of a fireless cooker. All you need to do is to get two store boxes of proper size and some packing material to be placed between the two as described above. Any family desiring the use of a fireless cooker can easily make one and enjoy the increased flavor of their food cooked in such a manner.



CROSS-  
SECTION OF  
THERMOS  
BOTTLE

*A* is material in the inside bottle.  
*B* is the outside bottle.

The "thermos bottle" is a modified form of the fireless cooker. It is made of two glass bottles, one sealed inside of the other at the neck in such a way that air cannot pass in or out between the two bottles. Just before sealing the inside bottle to the outside one, the air between the bottles is pumped out, thus leaving nothing between the two bottles which can transmit heat from the inside bottle to the outside one by convection or conduction. The outside bottle is lined on the inside by a bright, reflecting metal which prevents the escape of any heat from the inside bottle by radiation.

#### QUESTIONS AND EXERCISES

1. Why do gardeners make hotbeds with glass tops?
2. Why does an iron handle of a cooking utensil get so much hotter than a wooden handle?
3. What advantage is it to birds to have their feathers standing out straight from their bodies in winter instead of lying down smooth as in summer?
4. Why do animals living in cold regions have a heavy coat of fur?
5. How does clothing keep you warm in winter? In summer?
6. Why are cold storage rooms built with a double wall and the space between filled with sawdust or other material?
7. Why will ice packed in sawdust not melt?

8. Examine your heating system. What kind is it? How does the heat of the fire get to the air in the rooms?

9. Light a candle and take it to different parts of the room and note which way the air is moving. Make a drawing to show the circulation of the air.

10. Steam comes into the steam radiators at a temperature of  $100^{\circ}$  C. and the water of the condensed steam flows from the radiator at about the same temperature; where does the heat that warms the room come from?

11. How much heat will the air in a room receive from a radiator in 12 hours if 10,000 grams of steam at a temperature of  $100^{\circ}$  C. come into the radiator each hour, and if water flows out of the radiator at a temperature of  $95^{\circ}$  C?

12. If boiling-hot food is placed in a fireless cooker, will the temperature of the food increase or decrease? Why? Will it cook? Why? Why will the flavor of food thus cooked be increased?

## CHAPTER XV

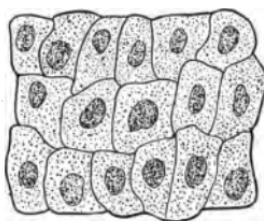
### FOOD

**77. The Human Body a Machine.** — The human body has certain characteristics similar to those of a locomotive or engine. It needs fuel from which to obtain energy for movement. This fuel must be oxidized to produce heat, which is transformed into muscular energy and enables the body to move about as the individual desires. The locomotive has in it fire from which the heat is transmitted to the water in the boiler. The water is changed into steam, the steam under the control of the engineer is allowed to pass to the cylinders and drives the piston back and forth by the energy which it received from the fire, and thus the heat energy of the steam is transformed into mechanical energy. The wheels of the locomotive are made to turn and the whole machine moves along the track.

The engineer in the cab of the locomotive corresponds to the brain in the human body. The engineer controls the locomotive by controlling the steam. The brain controls the energy in the human body by controlling the production of heat energy, its use, and its escape from the body. The locomotive, however, must have persons in charge of it and a continual supply of fuel to make it a machine by which work can be done. The human body needs a continuous supply of fuel, which is taken in the form commonly called food, but it does not

need an engineer or fireman. It is a self-controlling machine and is also able to obtain the fuel necessary to keep it in an active state.

**78. Cells.** — The whole human body may be thought of as a living organism which is made up of parts called organs, such as the heart, the lungs, the hands, etc. Each organ is made up of several tissues. For example, the heart is composed of muscular tissue, nervous tissue, connective tissue, and a few others. Each tissue is made up of smaller parts called cells. *A cell is the smallest division of a living body which can do the things necessary to sustain its life and that of the body of which the cell is a part.* The cells can take in food, can breathe, can throw off waste matter such as carbon dioxide and nitrogen compounds, and can grow and make other cells. These are called the functions of life.



FLAT CELLS FROM THE SKIN

In order that cells may carry on such activities, it is necessary for them to have a continuous supply of food, and the more active they are — as when a person is at work — the more food they need. There is no time when all the cells of the body are at rest, and on this account it is necessary to take food even when we are not at continuous or regular work. The cells in the human body keep up a continuous work of reconstruction and growth in order that the whole body may be in the best possible condition of health. When not enough exercise is taken to cause the waste matter of the cells to be carried away as fast as it is produced, and to cause a fresh supply of food to be carried to the cells, then the cells are not able

to do their best work and the whole body may begin to feel the results coming from the reduced activity of the cells. This condition of the body is usually known as sickness.

The cells of the body are very active; some organs never cease their activity except for fractions of a second; and new cells are continually being made in the body to replace the old ones which have been used up or oxidized. For these reasons a sufficient amount of food must be taken into the body to supply the fuel and the building material necessary to keep up all these vital activities. There are some foods which we eat that are used only for the production of heat, thus enabling the body to move about freely. There are other foods which are used for the repair of old cells that have been torn down and for building up new ones when the body is growing. All the foods that we eat may be divided into two classes, which are (1) nutrients and (2) inorganic foods like water and salt.

**79. Nutrients.** — The three nutrients are carbohydrates, fats, and proteids or protein. These are also called organic foods or organized foods. They all come from plants and animals. Since the body needs food both for the production of heat and for building material, it is necessary that we eat some foods which are easily oxidized and produce much heat, and also eat foods which are easily transformed into flesh and bone, so that the body may retain its weight. The body also will be kept more healthy if just a sufficient amount of each class of food is eaten to produce the proper amount of fuel and building material. In order to understand which foods are for fuel and which build cells, it will be necessary to study the three nutrients carefully.

(a) *Carbohydrates.* — Carbohydrates are so called because they contain hydrogen and oxygen in the same ratio as water, that is 2 to 1. Carbohydrates are composed of *carbon*, *hydrogen*, and *oxygen*. The pure forms of carbohydrates are *sugar* and *starch*. The chemical composition of starch is  $C_6H_{10}O_5$ , and that of grape sugar is  $C_6H_{12}O_6$ . From these compounds you can see that

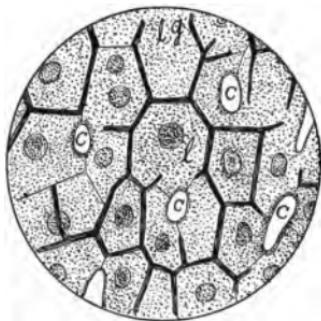


SUGAR FACTORY

the hydrogen and oxygen are in the same ratio as in water, that is, 2 to 1. The carbohydrates are digested in the mouth, in the stomach, and in the intestines, and are then carried by the blood to the liver, where they are stored, and given out and carried to all parts of the body as they are needed. A part of the carbohydrates is oxidized in the liver to make heat and the rest is oxidized in the blood and in the muscle. The part oxidized in the muscle produces energy which enables the body to move. Carbohydrates are also sometimes stored in the body in the form of fat; that is, fat is made out of the carbo-

hydrates by the body. Not very much food can be stored in the liver or in the muscle in the form of carbohydrates, and so a continuous supply of food must be going from the digestive organs to the liver and the other parts of the body. In order to keep up this supply, food must

be eaten every few hours, especially during the time when we are awake and are working hard.



LIVER CELLS

Where the glycogen is stored.

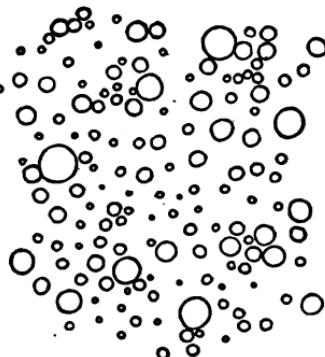
Foods which contain carbohydrates are those made of corn, wheat, oats, barley, etc. Apples, oranges, grapes, plums, peaches, and pears have carbohydrates, mostly in the form of sugar. Bananas when thoroughly ripe have both starch and sugar, and should not be eaten except when they are ripe. Bananas which have a green appearance are nearly all starch, and the starch is in such a condition that it is very hard to digest. Bananas in that state of ripeness should never be eaten. The starch in green bananas is about the same as the starch in raw potatoes and has nearly the same taste; both are very hard to digest. When the banana ripens the starch is changed to sugar, and when the potato is cooked the starch is acted upon by the heat and made easy to digest.

(b) *Fats.* — Fats are substances such as butter, lard, and tallow from animals, and olive oil, cotton seed oil, and linseed oil taken from plants. All the cereals like those which are made from corn, wheat, and oats have fat in them. Fat, being unlike sugar in composition, will not dissolve in water. Fats can be made to mix

with water by using a chemical base. Olive oil can be made to mix with water if a small quantity of ammonia or potassium hydroxide is added. When oils are mixed with water by the aid of a base the mixture is known as an emulsion. The most perfect emulsion, in which no base is used, is milk. Hot soups have more or less fat mixed with the water and are very poor emulsions.

Fats, like carbohydrates, are composed of *hydrogen*, *carbon*, and *oxygen*, but they do not have very much oxygen, and therefore a great quantity of oxygen is required to oxidize them. Since much oxygen is used in the oxidation of fats, they produce about *two and one-fourth* times as much heat as carbohydrates. The products coming from the oxidation of fats are water and carbon dioxide.

Fats are digested in the small intestines by the digestive fluid, which makes an emulsion out of the fat. This emulsion can pass through the walls of the intestine and get into the blood by way of the thoracic duct. (Ask the teacher to tell you more about it.) Soaps are also made in the intestine from fat for cleansing purposes. When soaps are made glycerine is also formed. The body uses the fat for making heat, which is done by oxidation. Fat is also stored up in various parts of the body for protection against cold and against possible injuries. The stored fat is also used at times when not enough food can be procured, or during sickness, for keeping the body temperature normal.



FAT GLOBULES IN MILK  
Highly magnified.

Because of the great amount of heat produced by fat when it is oxidized, the people living in cold countries, as the Eskimos in the North, must eat large quantities of fat in order to keep warm. They become accustomed to digesting large quantities of fat because their bodies need it. People living in a temperate climate like that of the northern United States usually consume more fats or fatty foods during the winter season in order that they may not suffer so much from the cold weather. In summer or in warm climates people naturally do not eat much fatty food. They do not have an appetite for such food, since the great amount of heat produced by the oxidation of fats is not needed during that time of the year. The appetite, if not perverted or spoiled by improper eating, is a comparatively sure guide in determining how much fatty food to eat.

(c) *Proteins.* — Proteins are foods which contain nitrogen and are sometimes called nitrogenous foods. The elements composing protein are *hydrogen, nitrogen, carbon, oxygen*, and some *sulphur*. Proteins are the building foods. They form about 80 per cent of the weight of the muscles of the body and are present in all the other tissues. When not enough carbohydrates and fats are eaten to produce the heat necessary to keep the body warm, the proteins are oxidized to make heat. But when proteins are oxidized, not only carbon dioxide is produced, but nitrogenous wastes also. The nitrogenous wastes are very poisonous to the body. They are taken from the body by the kidneys and the sweat glands, and these organs — especially the kidneys — may become diseased in throwing off the waste produced by the oxidation of proteins. For this reason it is best to eat just enough carbohydrates and fats to produce the heat

necessary and just enough protein for the building material. If such a balanced diet is eaten, the excretory organs of the body will not have so much work to do and so will remain healthy. Such a diet will also lead to a more nearly perfect health of the entire body.

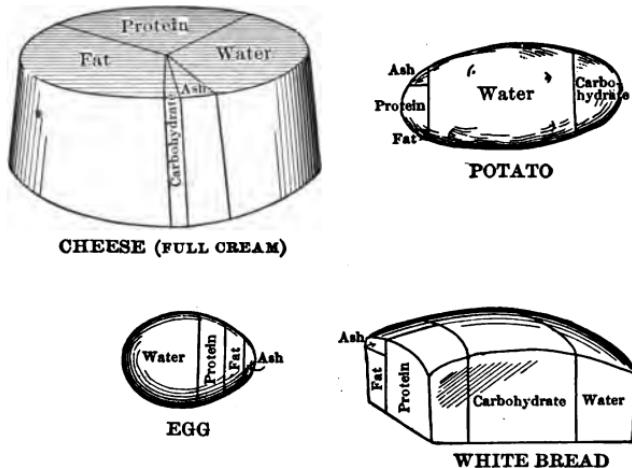
The white of a hen's egg is almost pure protein and water. When the white of an egg is heated it becomes solid; such a process is known as coagulation. Coagula-



BEEF IN COLD STORAGE

tion is the process of changing protein from a semi-liquid form to a solid. Clotting of the blood is a form of coagulation. The protein in the blood — called fibrin — forms a solid stringy material and encloses the red and white corpuscles. Casein is the coagulated protein of milk, out of which cheese is made. Gluten is the protein of wheat. It can be obtained by chewing whole wheat grains for several minutes and making no effort to swallow. The gummy substance left in the mouth is largely gluten. Gluten can also be obtained from flour by taking a tablespoonful of flour and wrapping it in a

piece of cloth; then wet it thoroughly with water and squeeze or work it between the fingers for several minutes, dipping it often in water to keep it moist. The substance left in the cloth after such a process is gluten. 'Gluten, being a tough, gummy substance, and somewhat elastic,



#### RELATIVE PROPORTIONS OF DIFFERENT NUTRIENTS IN WELL-KNOWN FOODS

prevents the escape of carbon dioxide from the dough when bread is permitted to rise.

Just enough protein should be eaten for the growth of the bodily parts and to rebuild partially worn out cells. The amount needed will depend upon the age of the person and the kind of work that he is doing. A person working in an office or in school does not require as much protein as a person who is engaged in hard physical labor like shoveling coal or working on the railroad. Men who are engaged in hard physical work can live well on such foods as meat and beans, because lean meat and beans have a large quantity of protein. Protein

in beans is more economical for use. Protein in meat costs from three to five times as much as the same amount of protein in beans.

**80. Water and Mineral Foods.** — The unorganized or mineral foods include water, common salt, calcium, and iron compounds. These are eaten in large quantities with the nutrients. Water is often taken separately, during meal time and between meals. The body is about 65 per cent water. What is the weight of the water in the body of a person who weighs 150 lbs? About 75 per cent of the beef on the market is water; 90 per cent of blood is water.

*Use of Water.* — Water is used in the body to carry food to all parts and to every cell. What is the name of the liquid in the body that carries the food? Water is used to liquefy the foods for digestion, so that they can pass through the walls of the digestive organs into the blood. Water keeps the body in a flexible condition so that it does not become stiff and rigid like dried beef. The water in the muscles permits them to contract and change their shape, and thus enables the whole body to move about. Unless a large percentage of the body were water we could not move about and be active in our work. About three quarts of water should be taken daily by each adult. These three quarts include the water which is taken separately and that which is in the foods when eaten.

The minerals in foods are used to form the framework of the body, such as bone and connective tissue, which give shape to the body and hold the cells in place. Lime and phosphorus help to form bone.

**81. Tests for Nutrients.** — Foods can be tested for carbohydrates by placing on them a few drops of dilute

iodine solution. For example, take a piece of bread and put on it some weak iodine solution. The color of the bread will become blue or bluish purple. Beans and cereals of all kinds can be tested in this way for carbohydrates. (To learn just the effect of iodine solution on starch in foods, put a little corn starch into a test tube and add some water, then put into the test tube a few drops of iodine solution and observe the color. This will serve as a sample color in testing foods for starch.)

To test foods for protein, observe the following: Take a piece of bread, put on it some strong nitric acid; if protein is present the bread will turn yellow. Now add some ammonium hydroxide and the yellow portion will change to orange if it is protein. Other foods can be tested for protein in the same manner.

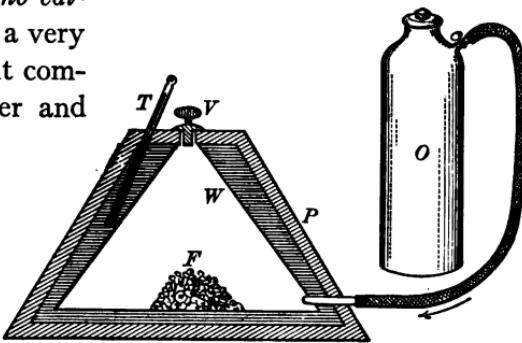
Foods can be tested for fats thus: Take a small quantity of corn meal, place it on white paper, and put the white paper with the corn meal on it into an oven which is not quite hot enough to scorch the paper. The oil in the meal will make a spot on the paper. Other foods can be tested for fats in the same manner.

To test foods for sugar, place a small quantity of the food in a test tube with some water, and put into it a few drops of Fehling's solution. Heat the mixture slowly over a Bunsen burner or alcohol lamp and watch the color of the contents in the test tube as the temperature rises. If sugar is present the color will first be a greenish yellow, changing to yellow, and finally to brick-red when the substance begins to boil. (To be sure of the colors in the test for sugar with Fehling's solution, make a weak solution of sugar and test it with Fehling's solution, observing the colors.)

**82. Fuel Value of Foods.** — Since two of the nutrients are used entirely for the production of heat in the body, and since the other one is often used in a large quantity for the same purpose, the fuel value of foods is determined by finding how much heat they will produce when oxidized or burned. In order to determine the fuel value of foods it is necessary to burn them in an apparatus known as the *bomb calorimeter*. This is a very simple instrument composed of an inner and outer chamber with a space between for water. The food to be burned is placed in the inner chamber and a thermometer is placed in the water between the inner and outer chamber.

The temperature of the water is taken. After the food is burned the temperature of the water is again taken. The weight of the water and of the food in the calorimeter must be known. The increase in temperature multiplied by the weight of the water in grams will be the amount of heat produced by the quantity of food burned.

The food calorie is larger than the ordinary or common calorie. *The food calorie may be defined as the quantity of heat necessary to raise the temperature of one kilogram*



BOMB CALORIMETER FOR DETERMINING THE FUEL VALUE OF FOOD

*F* is the food chamber; *W* is the water for receiving the heat from the burning food; *P* is packing to prevent the loss of heat; *V* is the entrance valve; *T* is a thermometer; *O* is the tank for supplying oxygen.

*of water one degree Centigrade.* The reason for using a large calorie in measuring the fuel value of foods is to avoid large numbers in recording the fuel value.

The carbohydrates produce the least amount of heat when oxidized, and so in order to produce the same amount of heat more of that nutrient should be eaten than of the other two. Fats when oxidized produce about two and one-fourth times as much heat as carbohydrates. Proteins produce about one and one-half times as much heat as carbohydrates when oxidized. But since protein is a building nutrient, an amount only sufficient for the growth and repair of cells should be eaten, while the other two nutrients should be eaten for the production of heat. The relative amounts of carbohydrates and fats that any one person should eat will be determined by the climate in which he lives, by the work done, and by the physical condition of the organs of the body. Carbohydrates and fats taken in the right proportion should be eaten in an amount sufficient for the production of just the necessary heat that the body requires. Eating the proper amount of each nutrient will give the bodily organs the least amount of work to do in throwing off poisonous waste products.

**83. Daily Fuel Needs of the Body.**—It has been stated that the amount of food eaten daily should vary according to climate, the time of the year, the occupation, age, etc. The following table gives the fuel needs of the body at various ages and occupations:—

#### DAILY CALORIE NEEDS (APPROXIMATELY)

1. For a child under two years . . . . .	900	Calories.
2. For a child from two to five years . . . . .	1200	"
3. For a child from six to nine years . . . . .	1500	"
4. For a child from ten to twelve years . . . . .	1800	"

5. For a child from twelve to fourteen years (women, light work also) . . . . .	2100	Calories.
6. For a boy twelve to fourteen years, girl fifteen to sixteen, and man of sedentary habits . . . . .	2400	"
7. For a boy fifteen to sixteen, man light muscular work . . . . .	2400	"
8. For a man at moderately active muscular work . . . . .	2700	"
9. For a farmer, busy season . . . . .	3200 to 4000	"
10. For ditchers, excavators, etc. . . . .	4000 to 5000	"
11. For lumbermen . . . . .	5000	"

**84. Bodily Heat Output.** — Some experiments have been conducted to determine the amount of heat which escapes from the body every hour. The following table will give some idea of the average escape of heat from the normal body while asleep, awake, at work, or at rest:—

**AVERAGE OUTPUT OF HEAT FROM THE BODY**  
*Condition of Muscular Activities*

	Average Calories per hour
Man at rest sleeping . . . . .	65
Man at rest awake, sitting up . . . . .	100
Man at light muscular exercise . . . . .	170
Man at moderately active muscular exercise . . . . .	290
Man at severe muscular exercise . . . . .	450
Man at very severe muscular exercise . . . . .	600

In order to determine how much heat is given out by a man, all you have to do is to calculate the number of calories given out for the hours spent in the various kinds of activities during the twenty-four hours. For example: Suppose we take a man working at moderate labor, who

Sleeps for nine hours . . . . .	$9 \times 65$	calories	585	calories.
Works for eight hours . . . . .	$8 \times 290$	"	2320	"
Reading and at rest at home seven hours.	$7 \times 100$	"	700	"

$\frac{3605}{}$  "

The following table will give some idea of the relative amounts of the nutrients in the various kinds of bread

TABLE I  
COMPOSITION OF VARIOUS SORTS OF BREAD AND SOME OTHER FOOD MATERIALS

Food Materials	Number of analyses	Refuse	Water	Protein	Fat	Carbohydrates	Ash
Wheat bread:							
From hard Scotch Fife spring wheat							
Minnesota							
Graham flour.....			47.20	7.76	1.27	42.82	0.95
Entire-wheat flour.....			49.16	7.45	1.14	41.73	.52
Standard patent flour.....			44.13	7.75	.90	46.90	.32
Second patent flour.....			42.10	7.75	.72	49.16	.27
First patent flour.....			44.40	7.48	.71	47.14	.27
From Oregon soft winter wheat							
Graham flour.....			38.55	6.11	1.12	52.68	1.54
Entire-wheat flour.....			39.95	5.70	1.09	52.39	.87
Straight grade flour.....			34.95	5.41	.89	57.85	.90
From Oklahoma hard winter wheat							
Graham flour.....			42.20	10.65	1.12	44.58	1.45
Entire-wheat flour.....			41.31	10.60	1.04	46.11	.94
Straight grade flour.....			37.65	10.13	.64	51.14	.44
Straight grade flour with 14 per cent bran.....			43.20	9.50	.84	45.55	.91
Straight grade flour with 7 per cent germ.....			38.00	11.07	1.13	49.12	.68
From miscellaneous flours							
High grade patent.....			32.9	8.7	1.4	56.5	.5
Standard grade patent.....			34.1	9.0	1.3	54.9	.7
Medium grade patent.....			39.1	10.6	1.2	48.3	.9
Low grade patent.....			40.7	12.6	1.1	44.3	1.3
White bread, average	108		35.3	9.2	1.3	53.1	1.1
Rolls.....	20		35.7	8.9	1.8	52.1	1.5
Crackers.....	71		6.8	10.7	8.8	71.9	1.8
Macaroni.....	11		10.3	13.4	.9	74.1	1.3
Corn bread (Johnnycake).....	5		38.9	7.0	4.7	40.3	2.2
Rye bread.....	21		35.7	9.0	.6	53.2	1.5
Rye-and-wheat bread.....			35.3	11.9	.3	51.5	1.0
Beef, ribs							
Edible portion.....	19		71.7	20.7	6.7	.....	1.1
As purchased.....	18	11.7	63.4	18.3	5.8	.....	1.0
Button, leg							
Edible portion.....	15		63.2	18.7	17.5	.....	1.0
As purchased.....	15	17.7	51.9	15.4	14.5	.....	.8
Cod steaks							
Edible portion.....	1		79.7	18.7	.5	.....	1.2
As purchased.....	1	9.2	72.4	17.0	.5	.....	1.0
Hens' eggs							
Edible portion.....	60		73.7	13.4	10.5	.....	1.0
As purchased.....		11.2	65.5	11.9	9.3	.....	.9
Butter.....			11.0	1.0	85.0	.....	3.0
Milk, whole.....			87.0	3.3	4.0	5.0	.7
Potatoes							
Edible portion.....	136		78.3	2.2	.1	18.4	1.0
As purchased.....		20.0	62.6	1.8	.1	14.7	.8
Apples							
Edible portion.....	29		84.6	.4	.5	14.2	.3
As purchased.....		25.0	63.3	.3	.3	10.8	.3
Chocolate							
As purchased.....	2		5.9	12.9	48.7	30.3	2.2

and in some other foods. By a careful study of the table one can determine the relative nutritive values of the different kinds of bread and also the relative nutritive values of the breads made from wheat grown in different parts of the United States. Compare the food value of bread with that of other foods by making a study of Table I, on page 126.

**85. Nutritive Ratio.**—Experiments in feeding live-stock have been conducted for many years in various parts of the United States. Many of these experiments have been conducted by the Agricultural Experiment Stations. The results of these experiments, showing how to feed live-stock, have been sent to the farmers. Farmers now know just how much of each nutrient to feed their horses, cattle, hogs, poultry, etc., in order to grow healthy animals and not waste any food. Many farmers are now more careful about feeding their animals than they are about the diet on their own tables. But people in the cities, who know little about feeding animals, are more apt to waste food than are the farmers, in the selection of their diet. Some experiments in human feeding have been conducted in order to educate the inhabitants of both the rural districts and the cities in the subject of foods. Professors Atwater, Chittenden, and Voit are noted authorities on human dietetics. The average of the nutritive ratios obtained by these three men, is 1 to 6 for adults. The ratio 1 to 6 means that one part protein to six parts of fats and carbohydrates should be eaten, or every time one ounce of building material (protein) is eaten one should eat six ounces of fuel food (fats and carbohydrates). The relative amounts of fats and carbohydrates that a person should eat depend upon the climate and the physical condition of the individual.

vidual. The nutritive ratio for children is about 1 to 4.2. The relative amount of protein in the diet should be gradually reduced from the time of childhood to maturity, at which time the ratio should be made comparatively constant at about 1 to 6. A slight variation should be made according to the occupation of the individual.

If the foods that are eaten have the proper nutritive ratio, there will be less waste, less poison for the body to dispose of, and the body will be well nourished and good health will result. The nutritive ratio of milk varies from 1 to 4.2 to 1 to 5. Wheat bread varies from 1 to 4.5 to 1 to 11. Corn bread has a nutritive ratio of about 1 to 7. To find the nutritive ratio of any food in Table I (page 126), multiply the percentage of fat by 2.25 and add the product to the percentage of carbohydrates, and then divide the sum by the percentage of protein. The result will be the number of parts of fats and carbohydrates to one part of protein. For example, milk taken from the table has 3.3 per cent protein, 4.0 per cent fat, and 5.0 per cent carbohydrates. Then the nutritive ratio of milk is  $3.3 + (4 \times 2.25) + 5$  or 1 to 4.2. To find the nutritive ratio from Table II (page 129), add the calories produced by the fats and carbohydrates and divide the sum by the calories produced by the protein. The nutritive ratio of milk in Table II is 19 to  $(52 + 29)$ , or 1 to 4.3.

**86. Varied Diet.** — By varied diet we do not mean that we should vary the proportionate amounts of the three nutrients — carbohydrates, fats, and protein. But the articles of food containing the proper nutritive ratio should be changed from time to time for several reasons, some of which follow. A limited variety of food should also be eaten at each meal. If only one thing is eaten

TABLE II  
FOOD VALUES, UNITS, AND PRICES

Name of Food	Portion containing 100 Food Units.	Weight for 100 calories	Calories furnished by			Price per Pound
			Protein	Fat	Carbo- hydrates	
<i>1. Animal</i>						
Beef (sirloin).....	Small steak.....	1.4	31	69	.....	30.
Brisket.....	Ordinary serving.....	1.80	42	58	.....	8.
Chicken.....	Large serving.....	3.2	79	21	.....	30.
Codfish.....	2 servings.....	4.9	95	5	.....	15.
Eggs.....	1 large egg.....	2.1	32	68	.....	30.
Ham.....	Ordinary serving.....	1.1	28	72	.....	25.
Lobster.....	2 servings.....	4.1	78	20	2	90.
Mutton (leg).....	Large serving.....	1.2	35	65	.....	18.
Oysters.....	1 dozen.....	6.8	49	22	29	25.
Pork (loin).....	Small serving.....	.97	18	82	.....	18.
Veal (leg).....	Large serving.....	2.4	73	27	.....	20.
<i>2. Dairy Products</i>						
Butter.....	Small pat.....	0.44	0.5	99.5	.....	35.
Buttermilk.....	1½ glass.....	9.7	34	12	54	4.
Cheese (American).....	1½ cubic inch.....	.77	25	73	2	25.
Whole milk.....	Small glass.....	4.9	19	52	29	5.
<i>3. Fruits, Nuts, etc.</i>						
Apples.....	Two.....	7.3	3	7	90	1.5
Bananas.....	One large.....	3.5	5	5	90	7.
Oranges.....	One large.....	9.4	6	3	91	7.
Watermelon.....	One whole.....	27.0	6	6	88	3.
Peanuts.....	13.....	.62	20	63	17	5.
Chocolate.....	½ square.....	.56	8	72	20	40.
<i>4. Vegetable</i>						
Beans (baked).....	Side dish.....	2.66	21	18	61	6.
Cabbage.....	4 servings.....	11.	20	8	72	2.5
Corn meal.....	Cereal dish.....	.96	10	5	85	4.
Crackers.....	2 crackers.....	.9	10	20	70	12.
Lettuce.....	5 average servings.....	18.	25	14	61	10.
Oatmeal.....	1½ servings.....	5.6	18	7	75	7.5
Potatoes (boiled).....	1 large size.....	3.62	11	1	88	1.5
Rice.....	Cereal dish.....	3.1	10	1	80	10.
Sugar.....	3 teaspoonsfuls.....	.86	..	..	100	6.
Tomatoes.....	4 average servings.....	15.2	21	7	72	6.
Wheat bread.....	Thick slice.....	1.3	9	7	84	5.

for a meal, the appetite usually ceases before a sufficient quantity of food has been taken to satisfy the needs of the body. Since every article of food needs its own active principle for digestion, and since the glands which secrete the digestive fluids can secrete only a limited number of enzymes at one time, the number of different articles of food eaten at one meal should not be great, but just sufficient to cause the appetite to remain normal

until enough food is taken to nourish the body. If too great a variety of food substances are taken during one meal, a part of them will go undigested. The meats and vegetables should be changed from meal to meal, or at least several times a week. A normal appetite is a comparatively sure guide in determining the kind and amount of food that a person should eat.

**87. When and How to Buy.**—Many families in the cities are suffering because of carelessness in buying foods. Many complaints about the "high cost of living" would be needless if more people would make a careful study of how, when, and what to buy and how to use the foods after they are bought. Foods should be bought when they are in season. "In season" is the time when the greatest amount and the best quality of a particular food are on the market; its price will then be the lowest. Foods which spoil easily should be bought only in such quantities as can be used without waste, while foods that can be stored without loss should be bought in larger quantities and direct from the producer if possible. For example, a man in Pittsburgh bought eggs from a farmer when they were plentiful and preserved them. This man was eating twenty-cent eggs when other people were paying 35 to 40 cents a dozen for them. Potatoes, dried fruits, canned goods, and cereals can be purchased in quantity while they are on the market in abundance. It must not be forgotten that a proper place to store food must be had when it is bought in large amounts. Cash payments will get more food for the money spent than time payments.

**88. Waste in Buying and in Use.**—There are some people who think that unless they are paying a high price they are not getting nutritious foods. Often the

less expensive foods are more nutritious and will make a healthier diet than the costly foods. "Recent studies have shown that if the proper attention were given to the tissue and fuel value of foods, the people of this country could purchase the same amount of nourishment that they now take for \$500,000,000 less annually than the present cost." In colleges where some students pay from four to ten dollars per week, the boys anxious to economize board themselves in their rooms for one dollar and fifty cents per week and some for less. As an experiment, a student changed from the expensive board to boarding himself. He purchased bread, butter, cereals, eggs, fruit, and only a little meat. He walked about five miles per day for exercise. At the end of the first four weeks he had gained four pounds. His board cost him  $16\frac{2}{3}$  cents per day or \$1.17 per week. He also took the highest scholarship rank in the college.

The nutrients in such foods as beef sirloin, fish, and oysters cost more than in any other form. Twenty-five cents worth of peanuts have fifty-three times as much fuel value as twenty-five cents worth of oysters. By a careful study of the figures in Table II, the relative cost of the nutrients in different articles of food can be learned. Figure out the amount of food that can be purchased for ten cents in the form of cereals or vegetables, and in the form of meats, and compare the results. Care in the selection of proper foods that are nutritious will save many a dollar.

There is also much waste in the care and preparation of foods in the home. Much loss occurs in improper cooking. Meats especially, when overdone, lose much of their flavor and are far less easily digested than when they are cooked rare. The reasons for cooking meats

are that the muscle fibers may be loosened and softened, and that the bacteria and other parasites in the meat may be killed by the heat. The common method of frying makes foods less digestible. Stewing is an economical as well as a healthful method. Slow boiling and roasting are excellent methods of cooking meat. The oven should be heated to a high temperature before the roast is put into it. The heat will cause a crust to form on the outer surface. This crust prevents the escape of the juices from the inside.

Vegetables are cooked so that the walls of the cells containing starch grains may burst and permit the starch to be easily acted upon by the digestive fluids of the body. Boiling water will dissolve out the nutrients from vegetables, so it is best to boil them rapidly or boil them in just enough water to prevent burning. Potatoes boiled in just enough water to prevent burning will be dry and mealy. They will have a good taste and will be easily digested. Vegetables should be cooked with the outer skin left on when this is possible.

#### QUESTIONS AND EXERCISES

1. Point out the ways in which your body can be compared to an engine.
2. Name the activities of a living body which are necessary for life.
3. Compare the meanings of "nutrient" and "nutriment." (See glossary.)
4. Name some pure carbohydrates. Do you get carbohydrates from plants or from animals?
5. Is fat used for the same purpose in our bodies as carbohydrates?
6. Compare the uses which the body makes of proteins with the uses made of fats and carbohydrates.

7. What substances are foods besides the nutrients?
8. From Table II select a sufficient amount of food for one meal that will have a nutritive ratio of 1 to 5.
9. Select enough food for three meals for five people that will have a nutritive ratio of 1 to 6.
10. Determine approximately the nutritive ratio of the last meal you ate.
11. From Table II determine whether you could decrease your cost of living without any injury to your body.
12. Keep an itemized account of all food purchased at home and see if any improvement could be made in quality and at the same time make a reduction in the cost.

## CHAPTER XVI

### WATER

89. The composition of water can be determined by decomposing it with an electric current after a few drops of acid have been added so that it will conduct electricity.

Two tubes filled with water, each one containing a platinum electrode, are connected with an electric battery or other current-producing apparatus with an electro-motive force of two or more volts. As the water is decomposed, one gas will collect in one of the tubes and the other gas in the other tube. When these gases are tested it will be found that one is hydrogen and the other oxygen. The tube containing hydrogen will have twice as much gas by volume as the one containing oxygen. This shows that water is composed of two parts hydrogen and one part oxygen, by volume.



HOFMANN APPARATUS FOR  
DECOMPOSING WATER

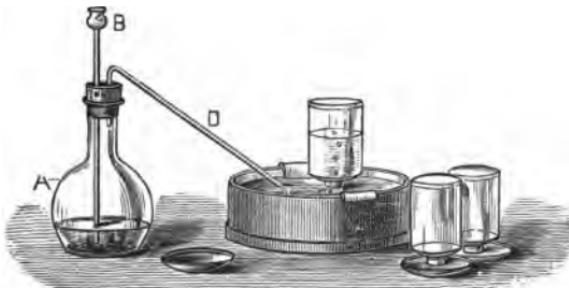
which has the greater amount of gas is supposed to con-

The way to test these two gases is as follows: The tube

tain hydrogen. If it is hydrogen, it will burn with a blue flame that is almost invisible in daylight, and will produce great heat. If the gas escaping from the tube containing the most gas is lighted and a larger long glass tube lowered so as to surround the flame, drops of water will be seen to collect on the inside of the larger tube. This water is a result of the union of the hydrogen with the oxygen of the air.

The gas in the tube containing the smaller amount will support combustion, if it is oxygen. If a glowing splinter of wood is held at the end of the tube where the gas escapes, it will burst into flame.

Pure hydrogen can also be obtained by placing pieces of zinc in a bottle, as shown in the illustration, and pouring



PREPARING HYDROGEN

on the zinc dilute hydrochloric acid. Collect the gas coming from the bottle by allowing it to pass through a tube into another bottle containing water and inverted in the pneumatic trough. *Caution.* — It will be found that if this hydrogen gas is mixed with oxygen and a lighted match placed at the mouth of the bottle an explosion will result, so the gas must be handled with some degree of care.

**90. Sources of Water.**—The sun is the great natural energy producer for the earth. The heat coming directly from the sun causes great quantities of water to evaporate from the land, the rivers, the lakes, and the ocean. Why does more water evaporate from the ocean than from elsewhere? The water which is thus evaporated is carried by the winds to various parts of the earth. Warm air can carry more moisture than cool air. When cool air is warmed its capacity for carrying water is increased. When warm air is cooled its capacity for carrying water is decreased. When winds from the ocean pass over a high mountain, they are cooled so that they are unable to carry the heavy load of moisture which they brought from the ocean. The moisture condenses, forms clouds, and falls as rain.

When the warm winds coming from the south are gradually cooled, their capacity for carrying moisture is decreased, so clouds are formed and rain is the result. When a cold wind from the north meets a warm wind from the south, clouds are formed suddenly and heavy rain falls. Since air expands when it is heated, it is forced upward by the cooler air surrounding the heated area. The air rising rapidly carries a large amount of moisture with it, but the air is cooled rapidly in the high altitudes and clouds are formed. Such cloud formations may sometimes produce what is known as a "cloud burst," which is nothing more than a sudden condensation of the moisture in the air and the descent of the moisture to the earth in the form of rain.

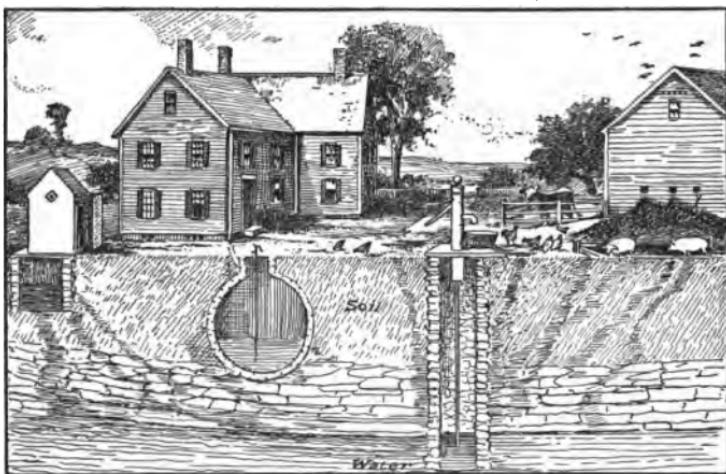
The continuous evaporation of water, the distribution of the vapor by the wind from place to place, the condensation of the vapor, the formation of clouds, and the falling of rain keep the water moving about over the

earth from place to place. The action of the sun on the water of rivers, lakes, and the ocean causes the land to be well supplied with moisture, which makes the production of both plants and animals possible.

**91. Why Water should be Purified.** — The decaying matter in the fields and woods — such as plants, leaves of trees, and animal matter on the surface — permits large quantities of poisonous substances and bacteria to get into the water. Many of these bacteria are not harmful, but there are some that are dangerous to health and are called disease germs. Some of the dangerous substances which get into the water from the surface of the earth are chlorine compounds. When water chemists of the cities find chlorine compounds in the water, they know that more or less decayed animal or plant matter has entered the water. There are various disease germs which can get into the water from the surface of the land, and sometimes these germs are carried beneath the surface and may flow into springs and wells. One of those that can be easily carried by water is the typhoid germ, or the typhoid bacillus.

People are sometimes careless of the waste matters of a patient who has typhoid fever. This waste may contaminate the water of their wells. These germs in the well water, if swallowed by a person in drinking, may produce the disease. Sometimes when a well is near the house and the waste water is thrown on the surface of the ground or poured into the sink, it may find its way into the well, carrying the germs with it. The surface of the ground or the soil is capable of oxidizing or destroying millions of germs, but the earth beneath, the subsoil, will not destroy disease germs readily, and so they may pass through the soil and get into the deeper parts of the

earth. These germs will flow with the water to the well, if there are no obstructing filters.



SOURCES OF CONTAMINATION OF CISTERNS AND WELL WATER

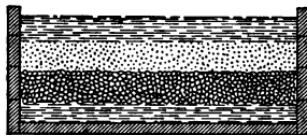
The illustration shows the liability of contamination from surface drainage and from entrance of filth at the top.

**92. Methods of Purification.** — *Boiling.* — One of the simplest methods of killing disease germs in water is by boiling it. Boiling, however, does not remove the disease germs, but simply kills them and leaves them in the water. Disease germs which are inclosed in an extra tough membrane are not killed unless the water is boiled for 15 minutes. Boiling does not always remove poisonous substances, as some chlorine compounds, from water.

*Distillation* is a process of purifying water by changing it into steam and then condensing the steam. The condensed steam is the purified water. Distilled water is free from germs and various other compounds which may have been dissolved in it. Distillation, however, is somewhat expensive, especially for private use. Most

cities require the manufacturers of artificial ice to distill the water before freezing it, in order that it may be free from germs and other impurities. For city use, distillation of water is impracticable because the large quantities of water used would make it too expensive. There is another method which is almost as effective.

*Filtration* is a process of purifying water by causing it to flow through sand and gravel. A great number of American cities are using the filtration process of purification. It prevents a great number of diseases, and especially typhoid fever. It also removes some of the harmful chemicals which are in river water. There are small charcoal and stone filters which can be attached to the water pipes in the private home and the water thus purified by filtration.



SECTION OF A SAND FILTER  
Showing impure water (top), sand, gravel, and filtered water.

These filters must be cleaned often or they will become a source of disease instead of preventing it.

**93. Use of Water While Camping.**—Since so many of the American people are beginning to spend part of their vacation in the open air, along some lake or stream, it is very important that they should be acquainted with some



A DRIVEN WELL FOR CAMPERS

of the dangers which they encounter when they use

water in such localities. Campers often contract diseases from the use of surface water, river water, and sometimes even from springs or from a near-by well. There are several ways in which these dangers can be avoided. The garbage of the camp should either be burned, buried, or carried quite a distance from the camp to prevent flies from collecting in great numbers. A place where there are no mosquitoes should also be selected. If water is taken from a running stream, it



A HILLSIDE CUT BY THE ACTION OF WATER

should be boiled before using it. Water taken from a well or spring should be tested before using, and if germs are found the water should be boiled. If there is no well or spring near, but a large stream, a well can be driven in a few hours near this stream and a pump put into the driven well. The well, of course, will have to be driven lower than the water in the stream. The water from the stream will filter through the sand and gravel into the well, which will usually be free from disease germs.

**94. Water a Solvent.**—Rain water is slightly acid, which enables it to dissolve more easily the rocks and

mineral salts in the earth. Water has aided in making the deposits of mineral salts found in the mountains as well as in lowlands. Through evaporation and through mixture with substances that will not remain together in solution, the salts that the water has dissolved have



A VALLEY MADE BY EROSION

been deposited in the bed of lakes or fissures in the rocks which the water once covered. If the larger part of the mineral in solution was an iron oxide, the deposit is a bed of iron ore. Many of the gold and silver veins in the Rocky Mountains were formed by the action of water. Mineral veins are also sometimes formed by precipitation. Ask your teacher how to form a precipitate, by pouring two solutions together.

If the surface water that is slightly acid flows into the ground and comes in contact with a layer of limestone, the acid will cause the limestone to be decomposed and gradually carried away by the water. After this action

has been in process for many years, an opening, called a cave, is left. There is in Kentucky a large limestone cave, which is called the Mammoth Cave. Such caves are also found in Virginia. Sandstone caves also are formed in the same manner as limestone caves.

*Erosion* is a process by which the surface of the earth is worn away by the water; the rock and soil are dissolved and some of the solid material also is carried away by the physical force of the water. The Grand Canyon, made by the Colorado River, is an example of erosion. The small ravines and gullies on hillsides where the timber has been removed are the results of erosion. Farmers need to guard against erosion in order to prevent the soil from being carried away. They usually protect the soil by keeping plants or grasses growing in their fields.

**95. Physical Properties of Water.**—The boiling point of water at sea level is  $100^{\circ}$  C. Since the boiling point varies with the pressure of the air or other gases on the water, on the top of a mountain water will boil at a temperature below  $100^{\circ}$  C. Water freezes at  $0^{\circ}$  C. in the open air. Water is at its maximum density at  $4^{\circ}$  C., that is, a cubic centimeter of water weighs more at  $4^{\circ}$  C. than at any other temperature. If water at a temperature of  $4^{\circ}$  C. is heated, it will expand. If water at  $4^{\circ}$  C. is cooled, it will expand slowly until its temperature is  $0^{\circ}$  C. At  $0^{\circ}$  C. water freezes and increases in volume about one-ninth. Nine cubic feet of water, when frozen, will become 10 cubic feet of ice. Which weighs more, a cubic foot of ice at  $0^{\circ}$  C., or a cubic foot of water at  $0^{\circ}$  C? To melt one gram of ice 80 calories of heat are required. How much heat will be given out when one gram of water at  $0^{\circ}$  C. freezes? To change one gram of water at boiling point into steam requires 536

calories of heat. How much heat will be given out when one gram of steam is condensed?

**96. Three States of Water.**—Water at ordinary temperatures is a liquid. The liquid can be changed into a solid by freezing. While water is freezing, heat is being taken from it. Heat is required to melt ice, hence ice is valuable for refrigeration. Liquid water can be changed to a gas by the addition of heat. The gas is called steam.

**97. Water and Climate.**—Except hydrogen, water has the highest specific heat of any substance and so a large quantity of heat is required to increase the temperature of inland lakes and seas. The water once heated requires a long time for the heat to escape. On account of this property of water, lakes do not change their temperature suddenly and so they do not vary in temperature very much throughout the entire year. For this reason large lakes and inland seas affect the climate of the country around them: the summers are not so hot; the spring season comes rather late; and the autumn is temperate. On account of the constancy of the climate, regions around large bodies of water are usually healthy places in which to live. Blossoming fruit trees in the springtime are less apt to be frozen if they are near a large body of water.

*Ocean currents* have great influence upon the climate of various parts of the earth. The Gulf Stream, flowing out of the Gulf of Mexico across the Atlantic Ocean to Europe, makes the climate of Western Europe mild and unchangeable. The Japan current, coming across the Pacific Ocean, touches the western shores of North America and makes a tropical climate in Southern California and a very mild temperate climate in Washington and Oregon. The climate along some coasts, such as

the New England States, is very changeable. The wind coming from the south is warm in winter, while the northwestern winds are extremely cold. In summer a southern wind is cool and a northwestern wind is usually warm. Ask your teacher to explain this. The climate of islands is kept nearly constant by the water around them.

#### QUESTIONS AND EXERCISES

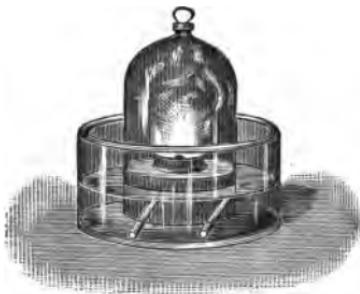
1. Of what two elements is water composed?
2. Why does it rain more on the western slope of the Rocky Mountains than on the eastern slope?
3. Is your water at home free from germs and harmful compounds?
4. What are the ways of purifying water? Which method do you use at home?
5. So far as water is concerned, what are the dangers while camping? How avoid them?
6. Are there any caves and valleys where you live? What made them?
7. On the basis of your own experience, is a cubic foot of ice heavier than a cubic foot of water?
8. Where does the water of the Gulf Stream get its heat to warm Europe? How does it carry this heat?
9. Why does San Francisco have a warmer climate than New York?

## CHAPTER XVII

### THE AIR

**98. The Air a Mixture of Gases.** — The air is composed of 79 per cent nitrogen, 20 per cent oxygen, .03 per cent carbon dioxide, some water vapor, and other gases. These gases — nitrogen, oxygen, and carbon dioxide — are mixed together, but are not combined chemically. When we breathe, the oxygen is separated from the nitrogen in our lungs. When natural gas burns, oxygen from the air unites with the carbon that is in the gas to form carbon dioxide. To prove that about four-fifths of the air is nitrogen, try the following simple experiment.

Take a piece of yellow phosphorus about the size of a pea, dry it with filter paper, and place it on a prepared float in a pneumatic trough. Ignite the phosphorus with a match and invert over it a cylindrical glass vessel. The phosphorous oxide formed will be absorbed by the water. The water will slowly rise in the vessel as the oxygen is consumed. The gas remaining in the glass vessel above the water is nearly pure nitrogen. Measure the gas and compare its volume with that of the entire vessel. This experiment gives evidence of what per cent of the air is oxygen.



TAKING OXYGEN OUT OF THE AIR  
BY BURNING PHOSPHORUS

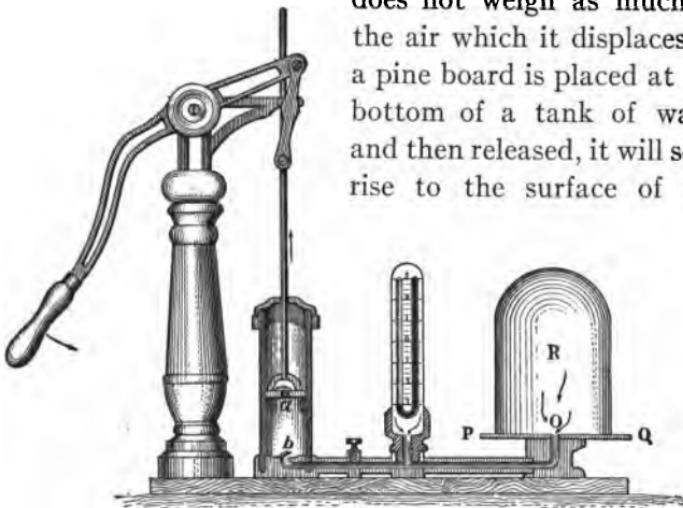
**99. Movements of the Air.**—Air, like the flowing brook and the waves of the sea, is never quiet or at perfect rest. If it moves less than 3 feet per second its movement is not perceptible to the body. Its speed varies from this unnoticeable movement to that of the raging tornado. These movements are caused by unequal heating in different localities. Air, when heated, expands and becomes less dense and is then forced away by the cooler air. The air at high altitudes moves more freely and faster than the air near the earth's surface. The movements of the upper air can be detected by observing the movements of clouds, which sometimes travel in a direction opposite to the way the wind is blowing near the ground.

**100. Density of the Air.**—The air surrounds the entire earth and when it is spoken of as a whole it is usually called the *atmosphere*. It extends from 50 to 100 miles above us. It is most dense on the earth's surface at sea level and rapidly decreases in density as one ascends. The air is so rare on the tops of the highest mountains that man or other animals cannot go there. It is even difficult for some people to stand the change in the density of the air while crossing the Rocky Mountains. About one-half of the earth's atmosphere by weight is within three miles of the earth's surface. Some air is in water, some in the soil, and some in the deepest openings in the earth.

**101. The Weight of Air.**—To the ordinary observer air does not seem to have any weight or to offer any resistance to objects passing through it. Recall some experiences that you have had and some unintentional observations that you have made and see if you think that air has no weight. A person running or riding on a bicycle can feel the air pressing against him with con-

siderable force, especially if the wind is blowing toward him. Everyone has experienced the force of the wind when he was passing around the corner of a building on a stormy day. You have seen balloons ascend or other objects float in the air. The balloon ascends because it

does not weigh as much as the air which it displaces. If a pine board is placed at the bottom of a tank of water and then released, it will soon rise to the surface of the



AIR PUMP

water. Because the pine board is not so heavy as the water which it displaces, the water forces it to the top. An object which is not as heavy as the air that is displaced by it will ascend for the same reason that the board does in the water. These everyday experiences give some evidence that the air is composed of matter. Matter is anything which has weight, and as air has weight it is composed of matter.

If air has weight then it should be possible to weigh it. Let us see if we can weigh air on scales. Get a rubber bladder from a football or basket-ball, force all the air out of it, and balance it on delicate scales or get

its weight to the tenth of a gram. Now pump as much air into the bladder as it will hold without bursting and weigh it again. When the bladder is filled almost to bursting capacity, it will weigh about half a gram more than when it is merely full. The increase in weight is due to the weight of the extra air forced into the bladder. A basket-ball with enough air in it to be used in a game weighs about three grams more than it does when it is empty. The air in the ball is more dense than the air outside. The air that is forced into the ball to make it more solid adds to the weight of the ball.

To find the weight of a given volume of air, try the following experiment. Take a glass bottle or other vessel that can be closed air tight, determine its volume and weigh it to a hundredth of a gram. Now attach it to the exhaust air pump and remove as much air as possible and then weigh it again. The difference in the two weights is the weight of the air pumped out. Divide the weight by the number of liters the vessel holds and you will have the weight of the air per liter. A liter of air at standard pressure and at  $0^{\circ}$  C. weighs 1.29 grams. Twelve cubic feet of air weigh a pound. Schoolrooms contain from 600 to 1000 pounds of air. Find how much your schoolroom holds.

It is evident from these experiments that air can be put into and taken out of a vessel. It can be weighed and handled like a liquid or solid. The air is a mixture of gases, it is matter, it has weight, and it is held on the earth like any other substance. It is drawn toward the center of the earth by the force of gravity.

**102. Air Pressure.** — *Pressure is force per unit area.* The areas most commonly used are the square inch and the square centimeter.

A book lying on the desk exerts a force equivalent to its own weight. Water in a vessel exerts a force against the sides and bottom of the vessel. Air is matter and so it also exerts a force on the sides of vessels containing it. You have experienced this with bicycle tires and footballs. Air also exerts a force on the earth's surface. This force is due to the weight of the entire atmosphere.

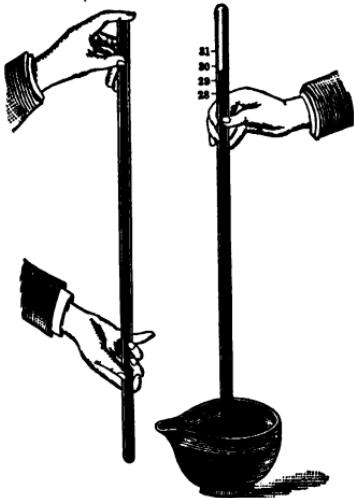
If a rubber membrane is stretched across a large opening in a glass vessel and the air is then exhausted from it, the membrane will be forced down into the vessel by the outside air pressure. Again, put a small quantity of water into a tin can that can be tightly closed by a cork, and heat it to boiling point. The air will be expelled by the steam. While the water is still boiling, cork the can tightly, remove it from the fire, and pour cold water over it. The steam inside will be condensed and the air outside will crush the can. When we drink lemonade through a straw, we exhaust the air from the tube and the pressure of the air on the liquid forces it up through the straw.

The height to which air will force water in a tube can be determined from the following experiment. Take a glass tube 34 inches long and closed at one end. Fill the tube with mercury, close the end with your finger, and invert it. Now place the bottom into a dish of mercury and remove the finger. Notice the mercury in the tube; it will fall a few inches, although no air can get in at the top, thus making a perfect vacuum in the top of the tube. The weight of the mercury in the



AS THE AIR IS EXHAUSTED THE SHEET RUBBER IS FORCED IN

tube is pressing on the mercury in the dish and the weight of the air is also pressing on the mercury in the dish. These two forces per unit area must be equal as the



MEASURING THE AIR PRESSURE  
WITH MERCURY

mercury does not flow into the tube or out of it. Hence the air pressure on the mercury in the dish is equal to the pressure of the mercury in the tube. By weighing the mercury in the tube, it can be found that it exerts a pressure of about 15 pounds per square inch when it stands at a height of 30 inches. Then the air must also have a pressure of about 15 pounds per square inch at sea level. That is, a column of air with a cross-section of one square

inch, extending upward as far as there is air, weighs 15 pounds.

If you have any doubt as to whether the open space above the mercury is a perfect vacuum, just incline the tube slowly and the mercury will fill the open space. If there were any air or other substance in the tube, the mercury could not go to the top of it when the tube is inclined. Now hold the tube erect again, and the mercury will fall to its former position. The perpendicular height of the mercury is what determines its pressure and not the length of the column when the tube is inclined.

Since mercury is 13.6 times as heavy as water, the air will hold water 34 feet high in a tube when it will hold mercury 30 inches high. When the mercury stands

lower than 30 inches the height of the water will be less than 34 feet. In the year 1640 it was accidentally learned that air would not lift water in a pump more than 32 feet above the surface of the water in the well. But at that time no one knew why. They did not know that the downward pressure of the 32 feet of water was equal to the pressure of the air at that particular place. Galileo, the great Italian scientist, was living at that time and he proceeded to investigate this strange action of the water. He died before finishing his task, and so it was left to his pupil, Torricelli, to continue the investigation and learn the truth in the matter. This he did in 1643.

Air is an elastic substance and so it can be compressed. The air at sea level bears the weight of all the air above it, and therefore it is very much compressed, and the molecules are much closer together than they are in the upper regions of the atmosphere. Twelve cubic feet of air at sea level weigh a pound, but twelve cubic feet of air at an altitude of 16,000 feet weigh only half a pound, and at an altitude of 15 miles the same volume weighs only about half an ounce. This shows that air decreases rapidly in density as one goes to higher altitudes.

This rapid decrease in the density and pressure of the air as we go upward explains why man and other animals cannot ascend to the tops of the highest mountains; also why balloons and flying machines cannot go many miles above the earth's surface. All birds and flying devices made by man depend upon the pressure of the air to sustain them and keep them from falling to the earth. The monoplanes and biplanes are, of course, heavier than the air which they displace, but they are kept from falling by being moved forward at a great speed with the planes set at such an angle that the air, which is being

continuously caught under the planes, causes the whole machine to be lifted before the air has time to move from under it.

**103. Barometers — Kinds and Their Uses.**—There are two kinds of barometers, the mercurial and the aneroid.



U. S. GOVERNMENT EXPERTS TESTING A BALDWIN DIRIGIBLE AIRSHIP

There are several types and modifications of each kind. Barometers do not, as some think, foretell the weather or measure the height of mountains. Barometers measure only one thing, and that is the air pressure. But air pressure and weather conditions have a very close relation. By hourly readings of the barometer one can tell whether the mercury is falling or rising and how fast. A falling barometer indicates foul weather and a rising barometer indicates the approach of fair weather. A comparatively sudden drop of the mercury means that a storm is approaching. After the storm is past the mercury will

rapidly rise again. By keeping a record of your readings of the barometer and your observations of the weather, you can learn to foretell the weather several hours or even a day or two in advance.

Since the density of the air decreases as one ascends a mountain, the height of the mountain can be determined by measuring, with a barometer, the air pressure at its base and on its summit. The mercury falls about one inch for every 900 feet of vertical ascent. If the mercury reading is five inches less at the top of a mountain than the reading at its base, how high is the mountain? The height of buildings and hills can also be determined by taking the readings of the barometer at the bottom and at the top. The height of mountains as generally given indicates the height of the summit above sea level. How is this found?

(a) *The Mercurial Barometer* is essentially the same as the simple barometer tube described in § 102. It was first used by Torricelli in 1643. The modern barometer has additional fixtures to prevent the mercury from spilling out of the cup or cistern and for accuracy in reading the height of the mercury column. This height varies from 29.2 to 30.5 inches, or from 73 to 76.5 cm., in localities which are not far above sea level. The reason for these changes in height is that disturbances of the atmosphere affect the air pressure at the earth's surface. Mercurial barometers can be made the most accurately, and are used in the United States Weather Bureau offices when careful observations are made.



A MERCURIAL BAROMETER

(b) *The Aneroid Barometer.* — Since the mercurial barometer is long and inconvenient to carry, geologists, surveyors, and mountain climbers commonly use the instrument called the aneroid barometer. It consists essentially of an air-tight cylindrical box, the top of

which is a metallic diaphragm which bends slightly under the influence of a change in the atmospheric pressure. If the air pressure increases, the diaphragm is pushed slightly inward; if the air pressure decreases, the diaphragm springs outward. This motion of the diaphragm is multiplied by a delicate system of levers, and is communicated to a hand which moves over a dial whose



AN ANEROID BAROMETER

readings are made to correspond to the readings of a mercury barometer. There are aneroid barometers made so sensitive that they will indicate a change in pressure when they are moved from a table to the floor. The weather conditions are printed on the face of these barometers because the barometric readings and weather conditions usually agree.

Some aneroid barometers have two hands, one fixed and the other movable. The fixed hand is set over the movable one at a certain hour and in reading the instrument one can tell whether the air pressure has increased or decreased since that hour, for the movable hand will change its position as the atmospheric pressure changes.

Some aneroid barometers are made in the shape of a

watch and are convenient to carry. The number of feet above sea level is marked on the dial, so that one can determine the elevation simply by looking for the number to which the hand points. These, however, must be set with the mercury barometer before starting on a trip to measure elevation; or if the reading is taken at the base of a hill and then at its top, the height of the hill above the plain can be determined, but not its height above sea level.

The *barograph* is a form of the aneroid barometer. Instead of having a hand moving around a dial to indicate the pressure, the barograph has an arm with a pen at the end, which writes the air pressure on a sheet of paper prepared for it. This sheet of paper has the hours of the day and the inches printed on it, and is fastened on a roller which is turned by clockwork. As the hours pass the roller turns and an ink line is made on the paper, indicating the air pressure.



A BAROGRAPH

**104. Air Currents.** — The atmosphere is constantly in motion, moving in various directions. When the air is rising in one locality, it is descending in another. When the air near the surface is moving north, a current above it is moving south. Currents above each other are usually moving in opposite directions. The two principal causes of the air movements are: (1) The unequal heating of the air by the earth's surface and (2) the varying amount of moisture or water vapor in the air. Either one of these causes affects the air pressure and hence affects the barometric reading. The wind blows toward the place where the barometer reads low and

from the place where the barometer reads high. These places in the air which cause a high and low reading of the barometer move across the United States from west to east. Rain or cloudy weather usually follows a low pressure and clear weather follows a high pressure. The air in a low pressure center is usually rising and cooling, and so clouds are formed, while in a high pressure center the air is falling and getting warmer, so instead of forming clouds it takes up moisture and is a drying wind.



A BIPLANE JUST LEAVING THE GROUND

*Aeronauts* who travel in balloons, airships, or aeroplanes have to study air currents. The lack of a knowledge of air currents has caused the death of many airmen. The aeroplane passing from one current into another may plunge to the ground, if the current just entered is moving in the same direction as the machine. Balloonists control their direction by ascending or descending until they get into a current going in the direction that they wish. The operators of airships have to be careful about passing from one current into another or their machine may take a sudden plunge to the earth.

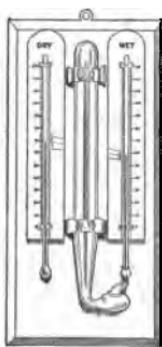
**105. Rain, Snow, Dew, and Frost.** — The heat of the sun causes continuous evaporation of the water of the oceans, lakes, and rivers, and some moisture evaporates from the land and from plants. This water vapor is carried by the air to various parts of the earth. Warm or hot air can carry more water vapor than cool or cold air can. The amount of water vapor in the air varies from day to day. Sometimes the air is very dry and at other times it has more moisture than it can carry.

To prove that there is moisture in the air when there seems to be none, let us recall some of our experiences. In summer the air is warm and usually has a great amount of moisture in vapor form which is invisible. If this air is cooled, it cannot hold its moisture in the invisible form. The vapor will collect in drops on cool objects like the outside of a vessel containing ice water. Cool water just taken from a well in summer and poured into a metal bucket will cause drops of water to collect on the outside of the bucket. These drops are formed from the condensed vapor of the air. If you want to see these drops of water form, pour a quantity of ice water into a metal vessel. When the water vapor of the air condenses on the cool grass or other objects at night, we call it dew. If it is sufficiently cold to freeze the dew, we have white frost.

When air has all the water vapor that it can hold without condensing it, it is said to be saturated. If warm air is cooled enough, the saturation point will be reached, and if the cooling is then continued the vapor will collect in small drops. If these drops collect on objects they form dew, but if they continue to float about in the air they form mist, fog, or clouds. When air is saturated, it is at the dew point. *Dew point* is that condition of

the atmosphere at which the water vapor begins to collect into droplets of water, becomes visible, and forms fog or clouds. If cooling is continued after the dew point is reached, heavy clouds will be formed, the drops will be too heavy for the air to carry, and they will fall as rain. If the air is below freezing temperature, the condensed vapor will be frozen and snow or hail will fall.

The *hygrometer* is an instrument used to determine the per cent of moisture in the air, that is, to ascertain how



HYGROMETER

near the air is to the dew point. The hygrometer determines the humidity of the air. Humidity is indicated on the instrument in per cent. *Humidity is the per cent of water vapor in the air, or it is the amount of vapor present compared to the amount of vapor that the air can hold at a given temperature.* If the humidity is 75 per cent at a temperature of  $85^{\circ}$  F., that means that the air has three-fourths as much water vapor as it can hold at that temperature. If the tem-

perature rises, the humidity will decrease unless more water vapor is added by evaporation. If the temperature falls, the humidity may increase until it reaches 100 per cent, when condensation will occur; 100 per cent humidity is dew point.

**106. Isobars and Isotherms.** — *Isobars* are the lines drawn on weather maps to connect places having the same barometric reading at a given time. Since the 128 Weather Bureau stations are at various altitudes, the barometers in the different offices have varied readings and would not mean anything if they were put on the maps as they are read; so the readings are reduced to what they would be if the stations were at sea level. Iso-

bars have no definite direction, but they run north and south more often than any other way. Sometimes they form circles. They are indicated on the weather maps by solid black lines.

*Isotherms* are lines connecting places having equal temperatures at the same time. Their general direction

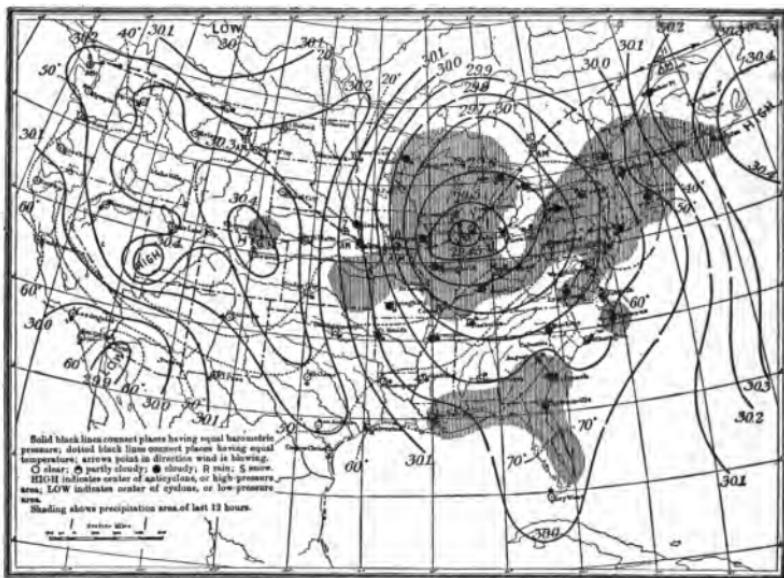


WEATHER BUREAU INSTRUMENTS AT THE ANNUAL EXPOSITION,  
PITTSBURGH, PA.

is east and west, but they shift to the north or south according to the elevation of the country and the direction of the winds. The isotherms now put on the weather maps indicate the temperatures which are multiples of ten. They are indicated on the weather maps by dotted lines.

**107. Weather Maps.** — In 128 different places in the United States are Government Weather Bureau Stations, at each of which accurate observations of the weather are made. These observations consist of reading the barometer and thermometer, ascertaining the humidity of the air and the amount of rainfall or precipitation

since the last observation, and determining the direction and velocity of the wind. These results are then telegraphed twice each day to the chief official in the Weather Bureau office at Washington. From these reports the



WEATHER MAP

*Isotherms*, dotted lines, drawn for every 10 degrees; and *isobars*, unbroken lines, drawn for every tenth of an inch. Line of arrows indicates the ordinary path across the U. S. of this type of low. Such lows usually advance at the rate of about 30 miles an hour.

chief officials predict what the weather is going to be in the near future. In the United States the general movement of the winds is from west to east, and if a certain kind of weather prevails anywhere in the west, it is possible that it will advance eastward, but many modifications may occur. So many influences change atmospheric conditions that infallible predictions cannot be made. But the Weather Bureau predictions do prove true often

enough to save many lives and prevent the destruction of much property.

Each local Weather Bureau office receives from the other offices the same reports that are sent to Washington. From these reports the local official predicts the weather for his locality and prints a daily weather map. The predictions are printed in the daily newspapers and on cards and on the maps sent out from the Weather Bureau office. By a careful study of these reports and the daily maps one can soon learn to foretell the probable weather conditions of the following day. The many signals and lines on a weather map are all explained at the bottom of each map. To understand the map it is necessary to become familiar with the signals and the meaning of the numbers and lines on it. The words "low" and "high" refer to the reading of the barometer. The word "low" is in a low pressure center and the word "high" in a high pressure center. Cloudy and unsettled weather follows a "low" center and fair weather follows a "high" center. The winds blow toward a "low" center and then rise, and they descend at a "high" center and blow from it toward the "low" centers.

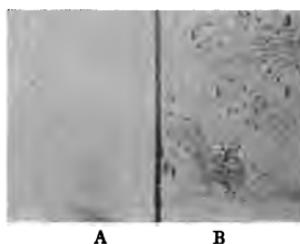


PUBLIC WEATHER "CAB"

Showing the hygrometer, barometer, rainfall gauge, thermograph, and maximum and minimum thermometers.

## QUESTIONS AND EXERCISES

1. What is the difference between a compound and a mixture of elements?
2. Is the air a mixture of gases or a compound?
3. Give the approximate composition of the air.
4. Compare the vertical extent of the atmosphere with the height of the highest mountain.
5. Why does a person's nose bleed while climbing a high mountain?
6. What causes a balloon to ascend?
7. Which is the heavier, a balloon ascending or an equal volume of air?
8. Which is the heavier, a bicycle tire pumped full of air or an empty one? Swimming wings full of air or empty ones?
9. What is the approximate air pressure in your schoolroom? Is it less than at sea level? Why?
10. Which is the greater, the downward pressure of the mercury in a barometer or the pressure of the air around the barometer?
11. When you drink a liquid through a tube, what causes the liquid to rise?
12. What are barometers used for?
13. What causes winds? Which winds bring rain? Do winds carry heat?
14. Explain the formation of dew. Make some dew form by placing very cold water or ice in a metal vessel.
15. What do isobars and isotherms indicate on weather maps?
16. Explain the meaning of the words, "high" and "low" on weather maps.
17. What kind of weather usually accompanies a "high"? "low"?



CHALKED PLATES from which the cast is made for printing the Weather Maps.

A, is the blank form; B, after the map characters have been cut out of the chalk down to the steel.

## CHAPTER XVIII

### SOME PROPERTIES OF GASES

**108. Gas Pressure.** — We have already learned that substances are composed of very minute particles called molecules and that these molecules are in motion. The molecules of water are so far apart that molecules of salt or sugar can occupy the spaces between them when salt and sugar are dissolved in the water. The molecules of gases are farther apart than those of water, and they move about faster than the molecules of water. When two gases are mixed, the molecules of the one occupy the spaces between the molecules of the other. Under ordinary conditions the two gases will remain mixed. Air is an example of such a mixture of gases. Since molecules cannot be seen with the best microscopes, it is evident that they must be very minute, and the number of them contained in a cubic centimeter of any substance is enormous. It may be that a thousand molecules laid side by side would not make a speck long enough to be seen with a good microscope.

That molecules, even in a quiet room, are in continuous and quite rapid motion can be proved by recalling some of our experiences. If an ammonia bottle is opened or the gas turned on without lighting it, the odor in a very short time will have become perceptible in all parts of the room. This shows that enough of the molecules of the gas to affect the nerves of smell have moved across the room. These molecules, being in motion and traveling at high speed, strike against one another and against

other objects. Since they are so numerous and strike against the wall of the vessel containing them, they produce what is called pressure. It is like a continuous pushing against a wall. If a stream of water from a hose is directed against a wall, it exerts a continuous

force due to the water molecules striking the wall. The air exerts a pressure of 15 pounds per square inch against the walls of a room at sea level. Within the tube of an automobile tire the molecules of air may produce a pressure of 100 pounds or more per square inch, and in a steam engine the pressure of the steam may be 200 pounds per square inch. The steam made from one cubic centimeter of water will occupy 1600 cubic centimeters of space when under about 15 pounds pressure. So in steam the molecules are 1600 times as far apart as they are in water and are moving much faster than they do in water.

Steam engines have a steam gauge

to measure the molecular pressure of the steam. There is a pressure gauge on the carbon dioxide tank of the chemical wagon of fire companies. These gauges in principle are very much like an aneroid barometer. Mercury gauges are also sometimes used; in these the gas lifts a column of mercury. Every two inches of the mercury column is approximately equal to one pound of pressure per square inch. The object in measuring the pressure of gases is to prevent explosions.



STEAM GAUGE



INTERIOR OF STEAM GAUGE

**109. Boyle's Law.** — *If the temperature remains constant, the pressure of a gas varies inversely as the volume.* If a cubic foot of gas is forced to occupy half as much space, the pressure will be doubled. If the pressure is increased from 10 pounds to 30 pounds, the volume of the gas will be one-third of what it was. We have learned that the pressure of a gas is due to the blows struck by an enormous number of molecules moving at high speed. To decrease the volume one-half is to double the density, and when double the number of molecules strike against the same area of the surface of the containing vessel the pressure is doubled. By calculation it has been found that air molecules under normal conditions move at the rate of about 445 meters (1390 feet) per second, while hydrogen molecules have the enormous speed of 1700 meters (5500 feet) per second. The speed of a cannon-ball is seldom greater than 800 meters per second. Since molecules move at such high speed, it is easy to understand why gases produce pressure and move almost instantly into the space left by the rising piston of an air pump, and why any gas always fills completely the vessel containing it.

**110. Compressed Gases.** — Gases are perfectly elastic and can be compressed or made more dense; that is, a given weight of gas can be made to occupy less space if pressure is put upon it. According to Boyle's law, if two cubic feet of gas are made to occupy only one cubic foot of space, the pressure of the gas on the sides of the containing vessel will be doubled if the temperature is constant.

The discovery of this property of gases has been very useful. Compressed air is one of the best springs that can be used. It would not be very comfortable to ride

on bicycles or in automobiles if it were not for the condensed air in the tires, making them act as springs. The Westinghouse air-brake, which is used on trains and street cars, depends upon compressed air for its operation. Compressed air is also used in drilling and riveting machines, without which modern skyscrapers reinforced with steel could not be built. Many kinds of hammering and stone-cutting machines are operated by compressed air.

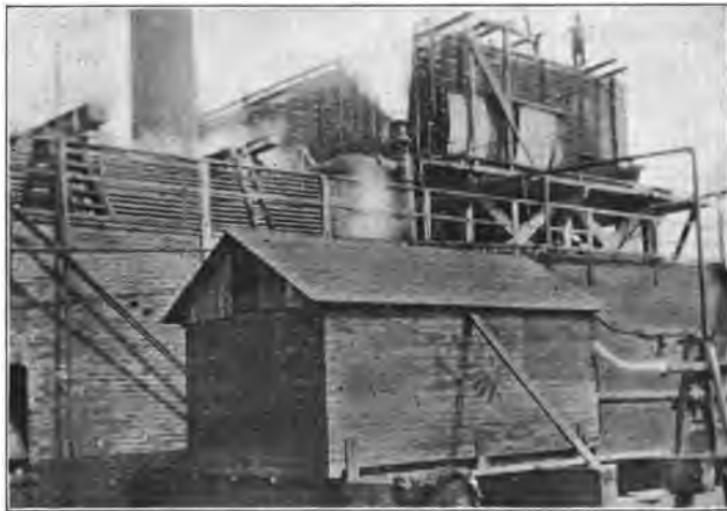
The gas formed by the explosion of gasoline vapor in a gasoline engine requires more space than the vapor, and so it sets the piston of the cylinder in motion. By a series of such explosions enough power is developed to run the machine. The compressed gas that drives the locomotive is steam. The force that compresses the steam comes from the burning fuel which causes the water to evaporate. Water is made to evaporate by causing the molecules to move so fast that they will not stay in the liquid. So many of the molecules of steam hit the sides of the boiler that they sometimes have a pressure of 250 pounds per square inch. When the engineer opens the valves the molecules rush through at an enormous speed and exert enough pressure on the piston in the cylinder to turn the wheels of the locomotive and thus move the whole train of cars.

Heat causes the molecules of a gas to move faster and to strike the sides of the containing vessel with greater force. To apply heat to a gas, then, will increase its pressure without increasing its weight or density. If the pressure on a gas is not increased when heat is applied, the gas will expand and become less dense. Balloons are sometimes filled with hot air, but they will descend as soon as the air in them cools to about the temperature of the air around them. Why? The air

on the earth's surface is compressed by the weight of the miles of air above us. When the air is heated it expands and becomes less dense, but its pressure remains practically the same, because the molecules move with greater speed and strike with greater force.

**111. Compression and Heat.** — When gases are heated either their pressure or their volume will increase. When air is heated it expands, becomes less dense, and occupies more space. If this expanded air is compressed, it will give out as much heat as it took up when it expanded. (Recall the law of conservation of energy.) The fact that air does give out heat when it is compressed has been experienced by everyone who has used a bicycle pump. After a few strokes are made the body of the pump becomes warm. This heat is partially due to the friction of the piston inside, but most of the heat is due to the fact that the air is being compressed; the molecules are being forced into less space, and they cannot move so freely, so their heat is given out. If compressed air is cooled and then allowed to expand, its temperature will fall and will take heat from surrounding objects. Let the escaping air of a bicycle tire touch your hand and see how cool it feels. When ammonia gas whose temperature is about  $15^{\circ}$  F. is compressed by a powerful engine, its temperature at once rises very nearly to  $200^{\circ}$  F. This increase in temperature is not due to the friction of the compression pump, but it is due to the fact that the molecules of ammonia are crowded closer together and the loss of energy in molecular activity appears in the form of heat. If this compressed ammonia gas is permitted to expand again, its temperature falls to what it was at first. In general, *when gases are compressed, they give out heat, and when they are allowed to expand they take up heat.*

**112. Refrigeration.** — From the facts in § 111, we can easily understand that gases can be used for cooling purposes. When fruits and vegetables are placed in cold storage a freezing temperature is not desired, so air can be used to keep the building cool. The air is compressed and forced through metal pipes with water running over them to cool the condensed air. This air is then allowed to escape in the storage rooms, which are thus kept at a low temperature.



AMMONIA CONDENSING PIPES ON THE ROOF OF AN ICE PLANT

Liquids, when they evaporate, take up a great amount of heat; this we know from our experience with water. To experience the cooling effect of evaporating liquids, place a few drops of the following compounds on the back of your hand in the order named: — ether, alcohol, ammonia, and water. The one that evaporates the fastest will feel the coolest, because the faster the molecules

leave your hand the more heat is required to supply the energy necessary for them to fly away.

The compound that is used for refrigeration by evaporation is ammonia, ( $\text{NH}_3$ ). Ammonia at ordinary pressure and temperature is a gas. At  $-40^\circ \text{ C}$ . it condenses and forms a liquid, or it can be made to liquefy at a higher temperature if the pressure is increased. The ammonia is purchased in liquid form in long cylindrical tanks. The cold-storage buildings in which ammonia is used have a system of closed iron pipes, compression pumps, and a place to liquefy the ammonia by cooling it after it is compressed by the pumps. The ammonia is put into this system of pipes, from which it cannot escape. It is made to circulate by the pumps. The pumps compress the ammonia gas and it is then cooled and liquefied while passing through pipes over which cool water is kept flowing. The cooling pipes are usually in the open air, often on top of the building. After the ammonia is liquefied, it flows to the cold-storage rooms, where it is permitted to pass slowly through valves, and then it evaporates rapidly because the pumps draw off the ammonia gas as fast as it is formed by evaporation. The evaporating ammonia takes the heat from the pipes in which it is enclosed and the pipes in turn take heat from the air in the room, which is thus kept at a very low temperature, even below freezing if desired. Large meat-packing firms and sometimes small meat-markets use ammonia for refrigeration. Ice is also used for refrigeration, especially in refrigerator cars and in private houses.

**113. Artificial Ice.** — Ice in the summer used to be regarded as a luxury, but now it is a necessity; without the modern methods of making ice, it would be very expensive. Boards of health require artificial ice to be

made of distilled water, and for this reason it is purer and more free from germs than the ice of rivers or lakes.

The water to be frozen is put into a metal tank that holds about 300 pounds, as shown in the illustration.



DRAWING 300-POUND CANS OF ICE FROM THE SALT WATER

These tanks are usually about four feet high and they are lowered into a large tank of salt water, which generally covers as much area as a large room, but not deep enough to permit the salt water to flow into the freshwater tanks. The temperature of the salt water is kept at about  $14^{\circ}$  F. or  $-10^{\circ}$  C. (A saturated solution of salt water freezes at  $-22^{\circ}$  C.) The temperature of the salt water is kept low by ammonia pipes which are in the salt water between the rows of freshwater tanks. The ammonia here goes through the same process as that described in § 112 on refrigeration with

ammonia. It requires about 36 hours for the 300 pounds of water to freeze into a solid piece of ice.

**114. Liquid Air.**—Steam is a gas and can be liquefied by subjecting it to great pressure or by cooling it. Ammonia ( $\text{NH}_3$ ) under ordinary conditions is a gas, and it can be liquefied by cooling or by adding pressure. It can be more easily liquefied by both cooling and increasing the pressure. By cooling a gas the molecules become less active and by using pressure they can be forced closer together. If the cooling and increase of pressure are continued far enough, the molecules become so inactive and so close together that the force of attraction which they have for one another overpowers their force of free motion. When molecules are in this condition we have what is usually called a liquid. (In some cases it would be a solid.) Then, in order to make a liquid of any gas all that needs to be done is to lower the temperature of the gas and increase the pressure on it. Air, oxygen, and hydrogen can be liquefied in this way. Under average air pressure, liquid air will boil on ice. In 1900 a temperature of  $-260^{\circ}$  C., or  $-436^{\circ}$  F., was produced by Professor James Dewar, by evaporating liquid hydrogen in a partial vacuum.

**115. Natural and Artificial Gas.**—During the millions of years while the earth's present crust was in process of formation, great quantities of plant and animal matter were buried beneath the surface. We now remove much of this material in the form of coal, petroleum, and gas. This gas is taken out of the earth by drilling wells, from which it is allowed to flow through pipes to the storage tanks of cities. From these tanks the gas is piped to houses for heating, cooking, and lighting.

*Artificial gas* is made by heating wood or coal in ovens

made for the purpose; no air can get into the ovens. The gas that comes from the heated coal is forced through water and various substances which remove all the solid matter and other undesirable elements. The pure gas is then forced into storage tanks from which it is piped to buildings for the same uses as natural gas.

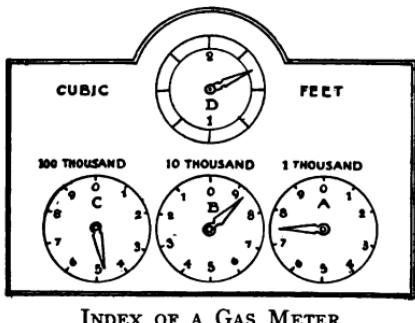
George Westinghouse invented a convenient device for measuring the gas as each customer burns it. This operates much like the apparatus in the steam chest and cylinder on an engine. The gas meter is composed of a metal case divided into two parts by a movable diaphragm, and a clockwork device records the movements of this diaphragm. When the gas flows into one side of the meter the diaphragm is forced over and the gas on the other side is forced out to the burners; when one side of the meter is full of gas the entrance valve closes and the entrance valve of the other side opens, and through this the gas enters and forces the diaphragm

to the opposite side and the gas of that side flows out to the burners. The movements of the diaphragm are recorded by the dials on the gas meter.

Gas is measured by the cubic foot and is paid for by the thousand

cubic feet. Every person who uses gas should know how to read a meter. A meter with four dials will give four digits, to the right of which we add two ciphers, thus, 263,800. (Provided the four dials are all in a row.)

To read one of the dials we take the smaller of the



two digits on either side of the hand of that dial. We begin with the dial on the left and read toward the right, writing only one digit for each dial. The numbers over the dials mean that when the hand passes once around the dial you will have used as many feet of gas as the number over the dial indicates. If the number over a dial is "10 thousand," the hand on that dial will measure 10,000 feet every time it goes once around, and as it passes from one digit to another it measures 1,000 feet. Read the gas meter in the illustration.

#### QUESTIONS AND EXERCISES

1. Explain how gases produce pressure.
2. If we increase the pressure on confined gas, how will its volume be affected?
3. The pressure in an automobile tire in a cool garage is 70 pounds; how will the pressure be affected if the automobile is placed in the hot sunshine?
4. Why does the air escaping from a bicycle or automobile tire feel cool?
5. What practical use is made of the fact that gases take up heat when they are allowed to expand?
6. Visit some artificial ice-plant and explain the process used.
7. Give the origin of natural gas. How is artificial gas made?
8. Draw the dials and hands of your gas meter several days in succession, also record the number of cubic feet. Do the same for the electric meter. (Continue this until you know how to read both of them.)

## CHAPTER XIX

### SIMPLE MACHINES

**116. Evolution of Machines.** — Primitive man, who spent most of his time gathering food from the plants that grew wild and by killing wild animals, did not know much about even the simplest machines, and he had but little use for them. The first tool that he learned to use was the stone or club which he chanced to hurl at an animal for self-protection or to secure the animal for food. Later he learned how to make a sling of a piece of hide, with which a stone could be thrown with greater force, and by practice accuracy was developed. This device was the first machine which man used to subdue nature, and he has been busy conquering the forces of nature ever since. Probably the next machine which man used in the pursuit of game was the lever, by taking a stick to pry open a log or to remove a stone from a hole into which an animal had fled for protection. Next came a cutting device made of a sharp bone or stone.

After primitive man had learned to use these three simple devices, — the sling, lever, and crude knife, — he was well on the road toward civilization. They gave him something to think about. The thinking led to wider uses and modifications of the simple machines. He could now build a place in which to live and protect himself from his enemies. To live in one locality required man to store food when it was plentiful in order to nourish himself in time of scarcity. By combining the lever

and cutting tool, he made a machine with which he could dig up the soil and make it more favorable for the growth of plants. This was primitive agriculture. He also learned to befriend certain animals and to protect them with his weapons. Thus began primitive stock-raising and the use of animals as beasts of burden.

Then came a comparatively rapid development of machines for clearing the trees and stones from the fields, for transporting some of the trees and stones for building purposes, for erecting larger buildings, and in comparatively recent times for manufacturing and extensive transportation. But we must not lose sight of the fact that the simple devices and tools used by primitive man are still used by the most highly civilized people, but with modifications, improvements, and almost an infinite number of additional machines of all kinds. *The people of today have the enormous heritage of all the mechanical devices ever thought of by man from primitive times to modern.*

If the leading races of mankind had depended only upon their physical strength to subdue and conquer nature, instead of seeking to invent new devices and to discover new methods of obtaining food and shelter, the world today would be in the condition that is prevalent in the wild parts of Asia, Africa, and South America, where the natives still use only the crudest tools and implements of primitive man.

We sometimes wonder how people a few hundred years ago could live at all, when we think of the enormous amount of complex machinery in use today, transporting man from place to place and bringing him food and clothing from the most distant parts of the earth. The steamboat, railroad, telegraph, sewing machine, harvest-

ing machine, street car, telephone, all came into use during the past century. Without modern machinery it would not be possible to take coal, petroleum, and gas from the earth. To the scientists, the thinkers, who brought all these modern mechanical devices into existence, the world owes a debt which it never can pay.

**117. Definitions.** — In order to understand the principles of some of the simple machines, it is necessary to get a definite idea of a few words which are used in discussing them.

(A) *Energy.* — In the chapters on heat we often used the word energy, and we have some idea of its meaning. Coal and wood have energy which can be changed into heat by oxidation. Hot iron has more energy than cold iron, and this energy can be removed from the iron by plunging it into cold water. The water then has the energy which the iron had. *These objects have energy by virtue of their condition.*

We also have energy in our bodies and can use it at will. A boy coasting down a hill on a bicycle has enough energy to coast part way up another hill. A stone thrown into the water makes the water splash and wave, because of its energy. The energy of a falling hammer will drive a stake into the ground. *These objects have energy because of their motion.*

A boy on a sled on the top of a hill in winter has enough energy to take him to the bottom. A book held above the desk has sufficient energy, if permitted to fall, to shake the desk. Water in a city reservoir has enough energy to cause it to flow through the pipes to the houses. *These things have energy because of their position.*

So objects may have energy by virtue of their *condition, motion, or position.* Energy which is due to the

condition or position of an object is called *potential energy*. Energy of an object which is due to motion is called *kinetic energy*. *Energy is ability or capacity to move an object.* To walk requires energy because our body is the object moved. It requires energy to move a wagon, a car, or a train. Energy, like heat, cannot be thought of apart from some object or substance.

(B) *Force.* — We never use at one time all of the energy stored in our body, but only a part of it at one time. When we walk, throw a ball, turn a machine, or lift a book we use part of the energy of our body. The part of the energy that we use at any one time is called *force*. So force is the amount of effort exerted at any one time. Or, force is the energy which is in process of use; or, *force is the energy which is being used to move or hold an object.* Force, then, like energy, cannot be thought of apart from matter or objects.

To hold in the hand an iron ball which weighs a pound requires us to exert a "pound of force." A *pound of force* is the force exerted by the earth on a pound of mass or matter in pulling the matter toward its center. The earth's force or "pull" on an object is called *gravity*. To hold in the hand a ball which weighs a gram requires one to exert a "gram of force." The *pound of force* and the *gram of force* are two units of force. There is no unit of energy because we do not measure energy except when it appears in the form of force or heat, and then we call it force or heat respectively.

(C) *Work.* — If a 200-pound force is exerted upon a barrel weighing 400 pounds, no work is done if the barrel does not move. Holding a book in one place is not working. In these instances force is used, but no work is done. Picking up a book from the floor and placing

it on the desk is work. Carrying bricks or mortar up a ladder is work. We do work when we lift a 200-pound box into a wagon. We do four times as much work when we lift a 400-pound box into a wagon as when we lift a 100-pound box into the same wagon. We do four times as much work when we lift a 100-pound box up four feet as when we lift the same box up one foot.

From these statements we see that to do work it is necessary that the object be moved, that is, work is a result and not an effort. Work is a result of force and not force itself. The amount of work done depends upon the amount of the force and the distance through which the object is moved. To move a given object ten feet requires twice as much work as to move the same object five feet, but the force required is the same in each case. Twice as much work is done when a 100-pound object is lifted four feet as when a 50-pound object is lifted four feet; here the distances are the same but the forces are different.

*Work is the result of a force moving through a distance.* Or, work = force multiplied by the distance the force moved; or,  $W=f \times d$  ( $w$  = work,  $f$  = force,  $d$  = distance.)

**118. Unit of Work.** — Since force and distance can be measured, work also can be measured. The unit of work in the English system is the foot pound. The *foot pound* is the work done when a "pound of force" moves through a distance of one foot. If we lift one pound up one foot, we do a foot pound of work. To lift 10 pounds five feet we do 50 foot pounds of work. If a boy weighing 100 pounds climbs a ladder 10 feet high, he does 1,000 foot pounds of work.<sup>1</sup>

<sup>1</sup> In the metric system a unit of work is the gram centimeter. The *gram centimeter* is the work done when a "gram of force" moves through

**119. A Machine** is a device used to transform or transfer energy and to apply force for doing useful work. Illustration of how a machine can transform energy: when coal is burned in the fire-box of a boiler, the heat of the coal makes steam of the water, and the steam in running the engine develops mechanical energy, which can be made to develop electricity or electrical energy by turning a dynamo. The electrical energy can be changed back to mechanical energy and drive street cars along the tracks. All kinds of steam and gas engines and electrical machines are devices for transforming energy as well as for transferring it; while the simple machines are either devices for transferring energy or devices to which force can be applied and useful work result.

The simple machines are six in number: The (1) lever, (2) inclined plane, (3) wedge, (4) screw, (5) pulley, and (6) wheel and axle. Of these the lever and inclined plane are basic types. The pulley and the wheel and axle are modified forms of the lever, while the wedge and screw are modified inclined planes. All complex machines are only combinations of two or more simple machines.

**120. The Mechanical Advantage** of a machine is the ratio of the resistance (as, for instance, the weight lifted) to the force applied. The weight in pounds divided by the force in pounds gives the *mechanical advantage*. The mechanical advantage of a machine is also the ratio of the distance that the force moves to the distance that the resistance moves. That is, force distance divided by weight distance

a distance of one centimeter. If we lift a gram one centimeter, we do a gram centimeter of work. The smallest unit of work in the metric system is the *erg*. The gram centimeter is equal to 980 *ergs*. (An *erg* is the work done by a force of one *dyne* moving through a distance of one centimeter. A *dyne* is a force that can give to a gram mass an increase in speed of one centimeter per second.)

is the mechanical advantage. (The above statements do not take into consideration the loss by friction.) For instance, if by the use of a machine a 500-pound piano is lifted 10 feet by a force of 100 pounds moving 50 feet, the mechanical advantage of this machine is 500 pounds divided by 100 pounds or 5. Again, the mechanical advantage is  $50 \text{ feet} \div 10 \text{ feet} = 5$ . (Friction not considered.)

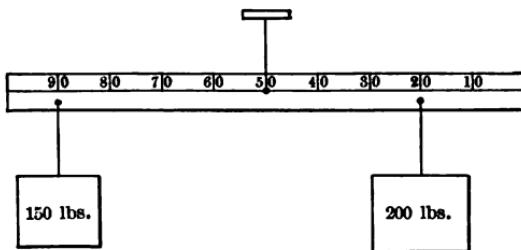
**121. Efficiency.** — Machines, especially the simple machines, are often thought of as devices for saving work. If a heavy object that could not be moved without a machine can be moved by the use of one, we are willing to waste a little work to accomplish our purpose. By the use of a machine the force applied does not have to be so great as it would have to be without the machine, but the force has to move much farther than the weight lifted to accomplish the desired result. Hence the work put into a machine is always equal to or greater than the work got out of the machine. *Work = force  $\times$  distance*, so the work put into a machine will be *the force  $\times$  the force distance*, and the work got out of a machine will be *the weight  $\times$  the weight distance*. The work got out of a machine will be less than the work put into it, if there is any loss by friction. All machines have more or less friction; when friction resists man's force in machines the efficiency of the machine is less than one, but if friction is assisting in mechanical work the efficiency is greater than one. The efficiency of a machine is the ratio of the work done by the machine to the work spent on the machine.

$$\text{Efficiency} = \frac{\text{Work accomplished}}{\text{Work spent}}$$

Efficiency is expressed in per cent; 90 per cent efficiency means that one part of the work spent on a machine is

wasted by friction and nine parts results in useful work. When an object is lowered by a machine, the efficiency of the machine is usually more than 100 per cent, because friction is resulting in useful work by helping to keep the object from descending too fast. Friction is useful in checking the speed of street cars and trains going down long grades and also for stopping them.

**122. The Lever.** — The *lever* is a rod free to turn about a point. The *fulcrum* is the point around which the lever turns. A seesaw is one kind of a lever: if the two persons on it are of equal weight, they take positions which are the same distance from the point about which the seesaw turns. If two persons of unequal weight get on a seesaw, the one who is the heavier will take a position closer to the fulcrum than the one of less weight. If a person whose weight is 100 pounds takes a position 6 feet from the fulcrum and a person whose weight is 75 pounds takes a position 8 feet from the fulcrum, they will balance on the seesaw. The reason that they will balance is because  $100 \times 6$  is equal to



LEVER OF THE FIRST CLASS

$75 \times 8$ . If a person weighing 50 pounds is 10 feet from the fulcrum and a person weighing 100 pounds is 5 feet from the fulcrum, they will balance, because  $50 \times 10$  is equal to  $100 \times 5$ .

Balance a meter stick as shown in the illustration, and

let a mass of 200 grams be hung by a thread from a point 30 cm. from the fulcrum. Then let a point be found on the opposite side of the fulcrum at which a weight of 150 grams will just balance the 200 grams. This point will be found to be 40 cm. from the fulcrum. We see the reason at once, because the product of  $200 \times 30$  is equal to the product of  $150 \times 40$ .

The seesaw and the meter stick, when used as described above, are levers. The important things to keep in mind about a lever are: (1) the large weight, which may be called the resisting force; (2) the small weight, which may be called the acting force; (3) the fulcrum, about which the lever turns; (4) the distance from the fulcrum to the weight, which is called the weight arm; and (5) the distance from the fulcrum to the force, which is called the force arm.

The law of levers is: *The force multiplied by the length of the force arm is equal to the weight multiplied by the length of the weight arm.*

$$\text{Force} \times \text{force arm} = \text{weight} \times \text{weight arm.}$$

For instance, 10 g. with a force arm of 10 cm. will balance 25 g. with a weight arm of 4 cm:  $10 \times 10 = 25 \times 4$ . That is, the moment of the acting force is equal to the moment of the resisting force. The *moment* of a force is that which is trying to produce rotation around a point. When the two opposing moments are equal there will be no motion and the lever will balance.

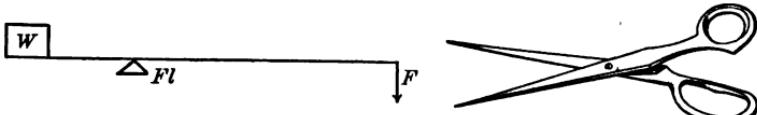
The *mechanical advantage* of a lever is (1) the ratio of the weight to the force, or (2) the ratio of the force arm to the weight arm, or (3) the ratio of the distance the force moves to the distance the weight is moved.

$$\frac{W}{F} = \frac{(1) F. \text{ arm}}{(2) W. \text{ arm}} = \frac{(3) F. \text{ distance}}{W. \text{ distance}} = \text{mechanical advantage.}$$

From the lever described on the opposite page,

$$\frac{25 \text{ g}}{10 \text{ g}} = \frac{10 \text{ cm}}{4 \text{ cm}} = 2.5 = \text{mechanical advantage.}$$

F. distance is the distance the force moved, and W. distance is the distance the weight moved. The force multiplied by the force distance (the work spent on the lever) is equal to the weight multiplied by the weight distance (the work accomplished by use of the lever). It is evident from this that the lever is not a machine to save work, but it is a device by which a large weight can be moved by a small force, but the force must move a much greater distance than that through which the weight lifted moves. For example, we can lift a 400-pound stone by a force of 100 pounds if we place one end of a lever under the stone and then place a block of wood or a small stone under the lever for a fulcrum, and then apply to the lever a force of 100 pounds at a point on the lever four times as far from the fulcrum as the fulcrum is from the weight. If the force arm is eight feet and the weight arm is two feet, the force will move four times as fast as the weight, and the force will move four feet while the stone moves one foot. The work done on the stone will be 400 pounds  $\times$  1 foot, or 400 foot pounds.

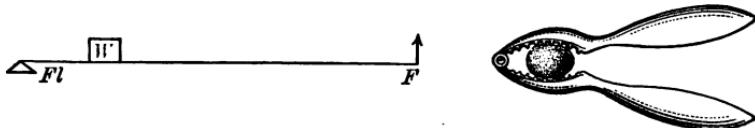


LEVERS OF THE FIRST CLASS

**123. Classes of Levers.** — Since there are three important positions on the lever, namely, the fulcrum, the position of the force, and the position of the weight, levers are divided into three classes according to the

position of the fulcrum with respect to the force and weight.

(a) The *lever* of the *first class* is one with the fulcrum between the force and the weight. Examples of this class are: common steelyards, scissors, the balancing arm of platform scales, most pump handles, and a crowbar when it is shoved under an object, a fulcrum put under and the force end shoved downward, thus lifting the object upward.

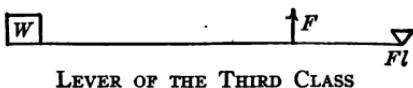


LEVERS OF THE SECOND CLASS

(b) The *lever* of the *second class* is one with the weight between the force and the fulcrum. Examples of this class are: the nut-cracker with the fulcrum at the hinge, the force at the handle (the weight is the pressure put on the nut to crack it); the wheelbarrow with the fulcrum at the axle of the wheel and the force at the handles; the foot when we stand on the toes, which form the fulcrum, the weight being on the ankle joint, and the force applied at the heel. In the lever of the second class the force arm is the entire lever-bar; the fulcrum is at one end and the force at the other. The force arm is the distance from the force to the fulcrum. The weight arm is the distance from the weight to the fulcrum. A bar 10 feet long will give a higher mechanical advantage if it is used as a lever of the second class than if it is used as a lever of the first class.

(c) The *lever* of the *third class* is one with the force between the weight and the fulcrum. Examples of this class are: the pitchfork with the weight on the end, the

left hand on the other end, which is the fulcrum, and the right hand between, which is the force; (if the left hand pushes downward and the right hand holds its



LEVER OF THE THIRD CLASS

position the pitchfork is a lever of the first class); the forearm with the fulcrum at the elbow, the weight on the hand, and the force applied just below the elbow joint; the whole arm with the fulcrum at the shoulder joint. In the lever of the third class the weight arm is the entire lever bar. The weight arm is the distance from the weight to the fulcrum. The mechanical advantage of the lever of the third class is less than one; the force is greater than the weight lifted. It is used to move small objects rapidly and with high speed, while the levers of the first and second class are used to move heavy objects with a small force. The bones of the body are used as levers of the third class, with the fulcrum at the joints, and powerful muscles with their tendons attached just across the joints act as forces to move the parts of the body with rapidity.

The lever of the first class can also be used for speed and for throwing objects, if the force arm is made short and the weight arm made long. This would require a large force to lift a small weight and the mechanical advantage would be less than one.

**Problems.** 1. In which of the three classes of levers do the following belong: a boat oar, grocer's scales, sugar tongs, a claw hammer, and a hatchet pulling a nail?

2. How would you arrange a ruler to use it as a lever of the first class, and then as a lever of the second class, in lifting a book?

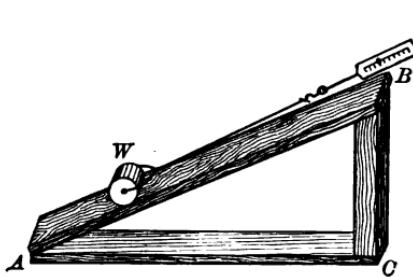
3. If a lever of the second class is 10 feet long, what is the mechan-

ical advantage if the weight is 2 feet from the fulcrum? How large could the weight be if a force of 100 pounds would just lift it?

4. If a lever of the first class is 10 feet long, and the fulcrum is 2 feet from the end, what is the mechanical advantage? How much force will be required to lift a weight of 600 pounds?

5. A lever of the third class is 10 feet long, with the force 2 feet from the fulcrum. What force is required to lift a weight of 10 pounds? What is its mechanical advantage?

**124. The Inclined Plane.** — The inclined plane is a simple device, often composed of one or more planks elevated at one end, so that objects may be rolled up or down. In order to understand the principle of the inclined plane, let us recall some of our experiences. We know that we become tired more quickly walking up a grade than while walking on the level, and the steeper the grade the more force it takes to ascend it. It is harder to ride a bicycle up a steep grade than to ride up a very gradual grade. The hill that is hard to climb in winter is the one down which we can coast the fastest. We can see from our own experiences that the slope of the plane is what determines the force required to roll



INCLINED PLANE

an object up it, and the length of the plane determines the amount of work done while rolling an object up it.

To test our observations let us try an experiment with a

plane, a rolling weight, and a spring balance. In the illustration, the length of the plane is  $AB$ , the height is  $BC$ , the weight moving up is  $W$ , and the force moving it is  $F$ , measured by the spring balance. If the height  $BC$  is

one-half the length  $AB$ , the force  $F$  is one-half the weight  $W$ . If the height  $BC$  is one-fourth the length  $AB$ , then the force  $F$  is one-fourth the weight  $W$ . Now let  $BC$  be 4 feet, the length  $AB$  be 8 feet, and the weight be 400 pounds; then the force will be 100 pounds, because the force multiplied by the force distance equals the weight multiplied by the weight distance:  $(200 \times 8 = 400 \times 4)$ . If  $BC$  is 2 feet,  $AB$  is 8 feet, the weight is 400 pounds, and the force is 100 pounds:  $100 \times 8 = 400 \times 2$ . From this experiment it is again evident that the work done by the force moving the length of the plane is equal to the work resulting from lifting the weight up the vertical height of the

plane, that is,  $F \times i = W \times h$ , and  $\frac{W}{F} = \frac{i}{h}$ , i. e. the mechanical advantage of the inclined plane is the ratio of the length of the plane to the height of the plane, or the ratio of the weight lifted to the force acting parallel to the plane.

The use of the inclined plane is for loading barrels or logs on a wagon and for unloading them; to roll or slide objects down into a cellar or for taking them out. By using a very long plane heavy objects can be loaded on a wagon with but little force. If the wagon is 3 feet high and the plane 18 feet long, a force of 100 pounds will roll a 600-pound barrel up on the wagon.

The grade of a highway or railroad is the number of feet that the road rises vertically per hundred feet. A railroad running straight up a hill a mile long (5280 feet) has a grade of 2 per cent, if the top of the hill is 105.6 feet above the level of the road at the bottom. The mechanical advantage of this grade or inclined plane is  $5280 \text{ feet} \div 105.6 \text{ feet}$ , or 50; hence, in order to pull a train to the summit

of the hill, the engine must exert a continuous force equal to  $\frac{1}{50}$  of the combined resistance of the train of cars.



RAILROAD GRADE WHERE ENGINES ARE USED ON BOTH ENDS OF A TRAIN

When building railroads and highways the grades are made very gradual wherever possible, because it requires much more work to pull a loaded wagon or train of cars up a steep grade than up a gradual one of the same length.

### 125. The Wedge



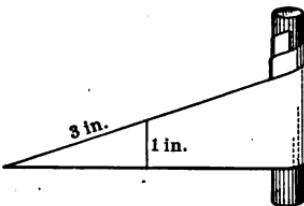
SHOWING THE USE OF  
THE WEDGE

is only a modified inclined plane. Some kinds consist of a simple inclined plane with a base and slope, and others consist of two inclined planes laid with the bases together and the slopes on either side. Wedges are used in splitting logs and stone, raising heavy weights and buildings a short distance, launching ships, and similar operations.

Chisels, axes, knives, and tools used for cutting are examples of wedges. The common pin is a wedge that

is widely used. Lumbermen use both iron and wooden wedges to split logs. An iron wedge 8 inches long and one inch thick at the large end, has a mechanical advantage of 8. If this wedge is struck with a five-pound hammer descending at a speed of 100 feet per second, it will lift a weight of 4,000 pounds. (The force of the hammer is  $100 \times 5$  or 500 pounds;  $500 \times 8 = 4,000$ .)

**126. The Screw** is a modified inclined plane. The threads of a screw may be thought of as an inclined plane wrapped around a rod. Since a lever of some kind is used to turn the screw, the whole machine may be regarded as a combination of the inclined plane and the lever. When the screw is turned once around it moves a vertical distance equal to the distance between the tops of two adjoining threads; this distance is the space between two adjoining threads plus the thickness of the thread. This vertical distance is called the *pitch of the screw*. So when the lever of a screw makes one complete revolution, the object on the screw is moved a distance equal to the pitch of the screw being used. Hence, the



SHOWING THE PITCH OF A SCREW

mechanical advantage of a screw is the result obtained by dividing the distance moved by the force used in making one complete revolution, by the pitch of the screw. If the pitch of a screw is  $\frac{1}{2}$  inch and the

lever 2 feet, the mechanical advantage is  $2 \times 2 \times 12 \times 3.1416 \div .5$ , or 301.5. If a force of 100 pounds were applied at the end of the lever, a weight of  $301.5 \times 100$ , or 30,150 pounds, could be lifted, if there were no friction.



SQUARE THREADS AND V THREADS OF A SCREW

Lifting jacks, cotton and hay presses, letter presses, vises, the screw propeller of ships, and electric fans are



JACK-SCREW



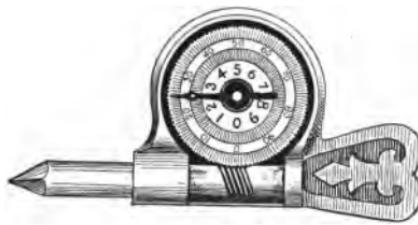
COPYING PRESS

familiar examples of the practical uses to which the screw is put. It is also commonly used in machinery

and woodworking.

The micrometer screw can be used to measure the thickness of a hair.

The speed counter is a screw turning in a notched wheel and is used to determine the



A SCREW FOR DETERMINING THE SPEED OF ROTATING WHEELS

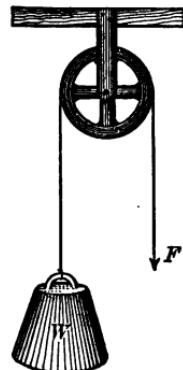
number of revolutions per second made by a wheel.

**Problems.** Find the mechanical advantage of an inclined plane 12 feet long and 3 feet high. Find the force required to roll a 600 pound barrel up the plane. How much work will be done in rolling the barrel to the top of the plane?

**127. Pulleys.** — The pulley is a modified first or second class lever. The center of the pulley is the fulcrum, the force can be thought of as though it were applied at one end of the diameter of the pulley. The weight is at the other end of the diameter, when the pulley is a first-

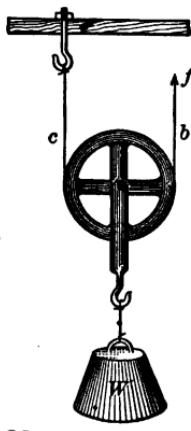
class lever. When the pulley is a second-class lever, the weight is at the center, the force is at one end of the diameter, and the fulcrum is at the other end.

(a) It is often more convenient to have a force act in one direction than in another, and the pulley is a very effective device with which to do this. It is much easier to have a pulley at the top of a flag pole, with a rope around it, and pull the flag up by pulling downward on the rope, than to climb the mast and pull up the flag. When a pulley is fastened in one position, as the one at the top of a flag pole, it is called a single fixed pulley, such as is also shown in the illustration. When a single fixed pulley is used we can easily find by experiment that the force applied is always equal to the weight lifted; hence the mechanical advantage is one, that is, no advantage at all except in changing the direction of the force.



FIXED PULLEY

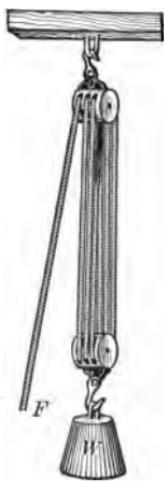
(b) The *single movable pulley* is one which is fastened to the weight and moves as the weight moves, hence it is called movable. In the figure, one end of the rope is fastened on the hook and the other end is attached to the force  $f$ . The pulley with the weight  $W$  attached is resting on the rope. Each strand of rope,  $c$  or  $b$ , holds one-half the weight, just the same as if the weight were hanging on two separate ropes. The pulley is now acting as a second-class lever whose fulcrum moves as the weight moves. The fulcrum is at the end of the diameter which the strand of rope,



MOVABLE PULLEY

coming from the hook, touches. The force arm is the whole diameter of the pulley and the weight arm is one-half the diameter. If the diameter is four inches, the force arm will be four inches and the weight arm two inches. The mechanical advantage of a single movable pulley, then, is  $4 \div 2$ , or 2. Hence the force required to lift a 200-pound weight is 100 pounds. The other 100 pounds of the weight is held by the strand of rope fastened to the hook. If two persons held the ends of a rope with a 100-pound weight hanging on it, each one would be holding 50 pounds, or one-half of the 100 pounds;  $100 \text{ lb.} \div 50 \text{ lb.} = 2$ , the mechanical advantage.

Since the strand of rope fastened to the hook does not



move when the force lifts the weight, the force will move twice as fast as the weight. When the weight is lifted three feet, the force will have moved six feet. Hence the work done by a force of 100 pounds is equal to the work accomplished on a weight of 200 pounds when it is moved 5 feet:  $100 \times 10 = 200 \times 5$ .

(c) *Combinations of Pulleys.* — When one or more fixed pulleys are combined with one or more movable pulleys, the combination is called a *block and tackle*. Heavy weights can be lifted by such combinations with a small force. Two or more pulleys may be fastened in one block, and when this block is securely attached, it is called the fixed block of pulleys. When a block of pulleys is attached to the weight which is to be moved, this is called the movable block of pulleys, or simply the movable pulleys, because they move with the weight. The fixed pulleys are used only to change

the direction of the force with respect to the weight and do not give any mechanical advantage. Only the movable pulleys give mechanical advantage. We saw in division (b) of this section that the mechanical advantage of a movable pulley is 2, and that there are two strands of rope, one going to the pulley and the other coming from it. So in order to find the mechanical advantage of a block and tackle, we count the number of movable pulleys and multiply that number by 2, or count the number of strands of rope going to and from the movable pulleys; the results are the same, if the rope is first attached to the fixed pulleys. In a system of two movable pulleys with a mechanical advantage of 4, a force of 100 pounds can lift a 400-pound weight. Since there are four strands of rope, the force will move four times as fast as the weight and also move four times as far as the weight; hence *the work done by the force will again be equal to the work accomplished on the weight.*

Combinations of pulleys are used in moving heavy furniture, pulling stumps, lifting heavy stones and timbers, moving small buildings, and in various other applications.

**Problems.** 1. What force will be required to lift a 200-pound weight with a single fixed pulley? With a single movable pulley?

2. Find the force needed to lift a 600-pound piano to a second story window with a block and tackle containing two movable pulleys. If the window is 10 feet high, how far will the force move while pulling the piano up?

3. What is the least number of movable pulleys that can be used in a block and tackle to lift a 2400-pound weight with a force of 300 pounds. How far will the weight move if the force moves 72 feet?

4. What is the largest weight that can be lifted by a force of 250 pounds applied to a block and tackle containing six movable pulleys? How far will the force have to move to lift the weight 5 feet?

**128. Wheel and Axle.** — The wheel and axle consists of a large wheel fastened to an axle which extends out from the wheel far enough so that a rope can be wound on it. Its mechanical advantage is explained by the



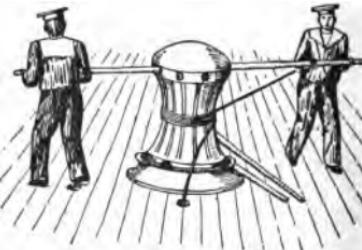
ONE FORM OF WHEEL AND AXLE

divided by the radius of the axle. Sometimes the rope is wound on both axle and wheel but in opposite directions. If the radius of the wheel is 2 feet and the radius of the axle is 6 inches, the mechanical advantage is  $24 \text{ in.} \div 6 \text{ in.}$  or 4. With such a system a force of 100 pounds will balance a weight of 400 pounds attached to the rope wound on the axle.

The *Capstan* is a form of the wheel and axle: the lever corresponds to the radius of the wheel, and the radius of the barrel corresponds to the radius of the axle.

**129. Windlass and Cogwheels.** — The windlass, which is extensively used for drawing water from wells, is a form of wheel and axle. When it is turned, the crank handle describes a circle which corresponds to the wheel

principle of the lever. The radius of the axle is the weight arm, the radius of the wheel is the force arm, and the center of the axle is the fulcrum about which the two arms turn. So the mechanical advantage of the wheel and axle is equal to the radius of the wheel



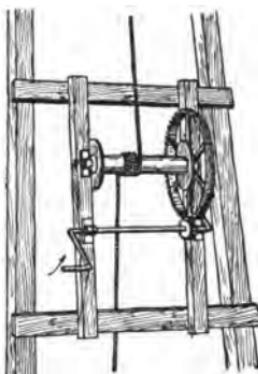
CAPSTAN OF A VESSEL

of the wheel and axle. The mechanical advantage of the windlass is equal to the result obtained by dividing the radius of the circle described by the crank by the radius of the axle.

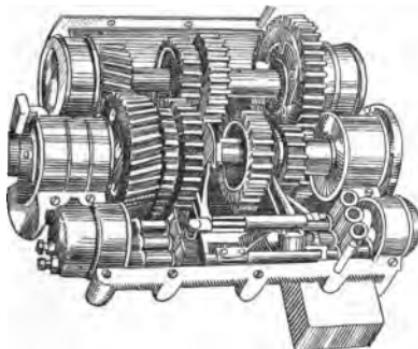
Cogwheels are also modifications of the wheel and axle, but the wheels which turn each other are fastened on different axles. The number of cogs on the large wheel divided by the number of cogs on the small wheel, will give the mechanical advantage; or the radius of the large wheel divided by the radius of the small wheel will also give the mechanical advantage. The sizes of the wheels can be made to have such a relation to each other that a very heavy weight can be lifted by a small force.

Cogwheels are also used to control the speed of machinery. Where high-speed engines are used, as in the automobile, the cogwheel attached to the engine shaft is a small one which turns in a larger one, thus reducing the speed of the wheels of the automobile. High speed of machinery can be obtained

by applying the force to a large cogwheel which turns a small one, or even a series of smaller ones, as is done on the cream separator.



COMPOUND WINDLASS OF A DERRICK



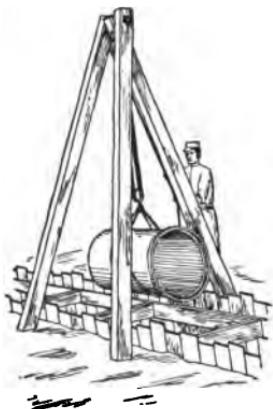
GEARING OF AN AUTOMOBILE

Belts and belt wheels are used for changing the speed of machinery and for the transmission of energy over a considerable distance so that it can be utilized in another place.

Very complex or compound machines can be made by combining two or more of the simple machines. The mechanical advantage of a compound machine is equal to the product obtained by multiplying together all the

mechanical advantages of the simple machines included in the structure of the compound one. By such combinations a very high mechanical advantage can be obtained. Derricks or travelling cranes used by railroads are usually combinations of block and tackle, cogwheels, and a windlass on which to wind the rope. The machinery in factories, printing establishments, and on Western farms is very complex, and these machines require a considerable amount of knowledge on the part of the persons operating them. Every successful farmer of today must be more or less of a machinist.

**130. Power.** — Review *energy, force, and work* in § 117 of this chapter. *Power* is the rate at which work is done, or it is the time rate of doing work. The word work does not include time. It requires just as much work to carry 200 bricks to the top of a 20-foot building in two days as it does to carry them up in two hours. We do just as much work when we walk to the top of a hill as when we run up. The force which we exert is much



HAND DERRICK

With hoisting tackle of  
rope and pulleys.

less when we walk up than when we run up the hill. The energy consumed in both cases is the same, but to run up consumes energy faster than to walk up. An engine that can do 100 foot pounds of work in a second has more power than one which can only do 50 foot pounds in a second; that is, the former engine can liberate energy faster than the latter. The former engine can also do more work in a day than the latter one. Since work and time can be measured, the power of a machine can also be measured by finding how much work it can do in a unit of time. Since the unit of work in the English system is the foot pound and the unit of time is the second, the unit of power is a foot pound of work per second, or

$$P = \frac{F \times d}{t} = \frac{W}{t} = \text{one foot pound per second when}$$

$W$  and  $t$  are unity. The work accomplished by a machine, divided by the time required to do the work, gives the power of the machine.

As the inch is too small a unit for measuring long distances, so the foot pound per second is too small a unit with which to measure the power of engines. James Watt, the inventor of the steam engine, chose a larger unit, namely, 550 foot pounds per second, for measuring the power of engines; 550 foot pounds per second is called the *horse power* (H.P.), because it was thought that an average horse could do 550 foot pounds of work in a second. The power of an average man is about one-seventh of a horse power. Railroad locomotives have several hundred horse power, varying from 500 to 1000, and the combined power of the engines of an ocean liner is many thousand H.P., sometimes as much as 70,000 H.P.<sup>1</sup>

<sup>1</sup> In the metric system the *erg* is the absolute unit of work, so the corresponding unit of power is the erg per second. This unit of power is

Since man himself does not have sufficient physical power to operate large, complex machines, he has learned to use the power (1) of animals, (2) of engines in which the power for their operation comes from the fuel burned in them, (3) of rivers and waterfalls which are made to flow over water wheels and develop power to run other machinery, (4) of the wind by building windmills for pumping water, and even (5) the power of the rays of the sun by building sun engines which transform the energy of the sun's rays into mechanical energy; these engines can only be run while the sun is shining, so a warm country with a cloudless sky is necessary for their successful operation.

#### QUESTIONS AND EXERCISES

1. What are some of the forces of nature that man has conquered? What use does he make of them?
2. When and by whom were the following invented: the telephone, telegraph, sewing machine, biplane, and steamboat?
3. Define energy, force, distance, work, and power.
4. Define the units of work and the units of power.
5. Draw the three classes of levers and name their parts.
6. Why is it better that the long bones of our bodies are used as levers of the third class?
7. Why do modern road-builders cut through hills and fill low places? What is a 3 per cent grade?
8. Does a combination of pulleys save work or waste work?
9. How find the advantage that the force applied has over the weight being lifted by a compound machine?

so small that it is customary to take as the practical unit 10,000,000 ergs per second. This large unit is called the *watt*, in honor of James Watt. Since the power of dynamos and electric motors is so great, a still larger unit is used to measure their power, called the *kilowatt*, which is equal to 1,000 watts. Engines are also being measured in kilowatts rather than in H.P. A horse power is equivalent to 746 watts, or about three-fourths of a kilowatt.

## CHAPTER XX

### WATER WHEELS AND WINDMILLS

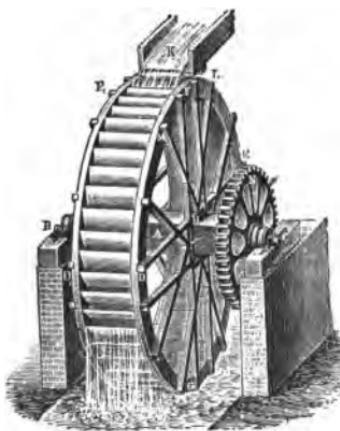
**131. Water Power.** — Every boy who has played in a running stream or with a sprinkling hose knows that swiftly flowing water has considerable force. It requires much greater effort to row a boat upstream than to row it downstream at the same rate. Water exerts a force in the direction in which it flows and so resists objects moving against the current and assists the movement of objects which are going in the same direction as the current. If a steamboat can go upstream six miles per hour when the current is moving three miles per hour, the same boat can go downstream at the rate of twelve miles per hour. In this case it requires twice as much work for the boat to go upstream as to go down the same distance. To overcome the resistance of flowing water is no small task in ocean and river commerce. The captains of ocean liners aim to run their vessels with the ocean currents as much as possible.

Mountain streams and waterfalls can be made to develop sufficient power to run mills, factories, and street cars, to light the streets and homes, and even to heat buildings. Niagara Falls, the greatest cataract in the world, is used by both the United States and Canada for the development of power, mostly in the form of electricity. Every pound of water in the Niagara River does about 150 foot pounds of work when it plunges over the falls. The millions of pounds of water of the Niagara, if utilized,

would develop enough power to supply the needs of many cities. But the natural scenery of such a cataract is considered to be worth more to civilization than the work which could be done by using its power.

To make waterfalls for the development of power, a dam is usually built in rivers and mountain streams. These dams also help to regulate the supply of water and to keep it under control. The supply of water must be constant in order to operate machinery successfully. Nearly all of the flour mills built by the early settlers of the United States were run by water power. Many of these can now be found in ruins. The largest flour mills in the world are run by water from the Mississippi river at St. Paul, Minnesota. Nearly all of the water of the Androscoggin River is used for power in Lewiston, Maine. This is true of many other rivers.

There are several types of water wheels now in use.



OVERSHOT WATER WHEEL

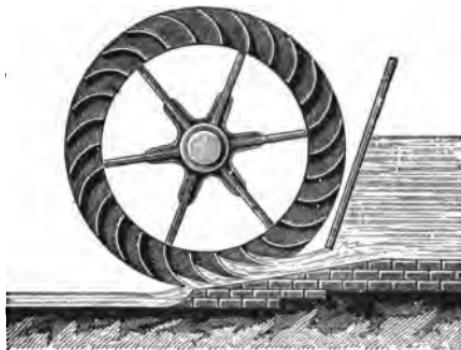
They are all made to receive the energy of the flowing water and transform it into mechanical energy. The type of wheel used is determined by the quantity of water available and the distance that it falls. The various types are the following.

### 132. The Overshot Wheel.

— The overshot wheel as shown in the illustration is made of a series of trough-like buckets into which the water pours at the top. The buckets empty their water at the bottom of the wheel and go up empty and upside

down. The weight and force of the water flowing into the buckets turn the wheel. This overshot wheel is used where the fall is not very great and its diameter is almost equal to the distance the water falls. The waste in power is due largely to the water spilling out of the buckets or shooting over them. The efficiency of such a wheel is from 80 per cent to 90 per cent. The power is transmitted by a shaft and series of cogwheels or by a belt.

**133. The Undershot Water Wheel.** — This is used in level countries where the fall of water is not great enough for overshot wheels, but where the water is in abundance. The wheel is built somewhat like the paddle-wheel on a steamboat, and the water strikes the wheel at the bottom with the force with which it flows into the mill-race from the



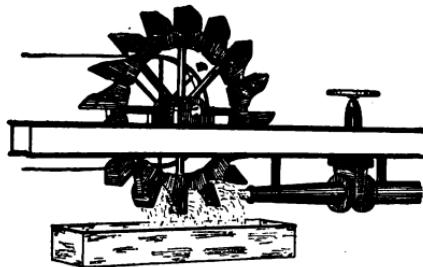
UNDERSHOT WHEEL

bottom of the dam. A type of the undershot water wheel is the one which boys usually make while playing in swiftly running streams. The efficiency of the undershot wheel is about 30 per cent when compared to the energy of the water above the dam.

**134. The Pelton Water Wheel or Motor.** — This is a modern form of the undershot wheel which has come into use since 1880. Small forms of it are used for small power machines in cities in which power can be had from the waterworks. It is also used where water is conducted down a mountain through pipes. The water

flows from a nozzle against spoon-like blades on the wheel. The efficiency of such wheels may be as high as 84 per cent.

**135. The Turbine Water Wheel**

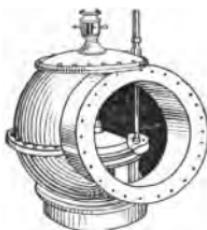


PELTON WHEEL

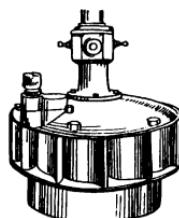
is made of thin blades set at such an angle that the water can strike them and cause the wheel to rotate. It is enclosed in an iron casing into which the water is permitted to flow for turning the wheel. The water falls through the penstock

and exerts a force that causes the wheel to rotate rapidly.

The turbine wheel was invented in 1883 and is now used more than any other wheel. It gives the best



Outer case



Inner case



Turbine wheel

PARTS OF A TURBINE

results if a waterfall of 10 feet or more can be secured. It is used exclusively at Niagara, where the water drops more than 100 feet before going through the turbine wheel. Some of the turbines at Niagara develop 5,000 horse power. One of the most powerful turbines in use is at Quebec, Canada. The water falls 135 feet, the

wheel is 10 feet in diameter, and develops 10,500 horse power.

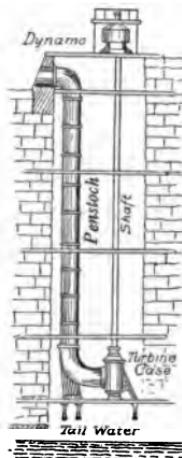
The energy of the turbine wheel is transmitted by a shaft to an electric dynamo or other machinery. There are turbine wheels which transmit for use 90 per cent of the energy of the falling water.

The diagrams illustrate the parts of a turbine and one installed.

### 136. Value of a Stream or Waterfall.

— Before any kind of water wheel is installed the quantity of water and the distance it can be made to fall are ascertained in order to determine the kind and size of wheel to use. A small wheel cannot transform all the energy of a large supply of water, and a large wheel cannot develop much power with a small quantity of water.

The quantity of water delivered by a stream can be determined as follows: Measure the width of the stream and the depth at intervals of 5 or 10 feet and take the average depth. Measure the speed of flow of the water by placing a float in the middle of the stream and see how far it moves in a minute. For example, suppose the stream is 50 feet wide; if the depths are 4, 6, 9, 7, and 5 feet, the average depth would be  $(4 + 6 + 9 + 7 + 5) \div 5 = 6\frac{1}{5}$  feet. Suppose the stream flows 4 feet per second. The quantity of water that would flow over a dam in a second would be  $50 \times 6\frac{1}{5} \times 4$  feet, or 1240 cubic feet. A cubic foot of water weighs 62.5 pounds. So the weight of water flowing over the dam per second would be  $1240 \times 62.5$  pounds, or 77,500



TURBINE AT NIAGARA FALLS

pounds. If the dam is 12 feet high, the work which the water would do per second would be  $77,500 \text{ pounds} \times 12 \text{ feet}$ , or 930,000 foot pounds. It would develop  $930,000 \div 550$  or 1690.9 horse power if there were no



DAM IN THE ALLEGHENY RIVER

waste. Such a stream would be valuable for running a flour mill or other machinery, but the turbine installed should be one which would develop about 1,000 horse power, as all of the water could not be made to pass through the wheel.

**137. Windmills.**—The toy wind wheel made of



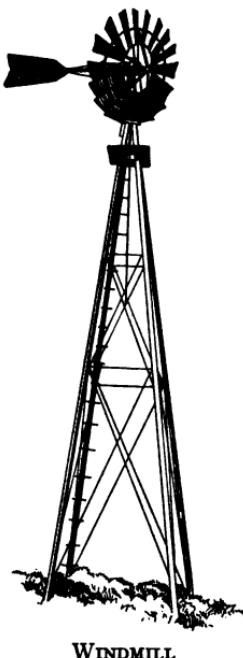
TOY WIND  
WHEEL

paper and fastened to a stick with a pin, illustrates the principle of the windmill. The air strikes the curved blades of the wheel at an angle and the wheel is thus turned by the force of the air. The wheel of a windmill is made of strong blades of wood or steel, sometimes curved like the blades of a toy wheel; sometimes the blades are flat but set at an angle so that the force of the wind causes the

wheel to rotate. The principle of the windmill is the same as that of the turbine water wheel; the moving substance or fluid strikes the blades of the wheel at an angle in each case and thus imparts mechanical energy to the wheel. The axle of the wheel of the windmill is rigidly fastened to the wheel. The axle has fastened to it a cogwheel that turns another wheel with a crank attached which moves the piston of the pump up and down as the wheel turns around.

The wheel of a windmill will not turn when it stands edgewise to the wind. It must stand perpendicular to the wind, that is, face the wind, in order to rotate. A tail-like fan is used to cause the wheel to face the wind. When the fan is perpendicular to the wheel the wheel will face the wind and rotate, but when the fan is pulled so that it stands edgewise with the wheel, the wheel will not rotate. By shifting the fan the wheel is thrown in or out of action. Most windmills are constructed so that they throw themselves out of action when the wind blows extremely hard.

Windmills are used mostly for pumping water. The water is kept out of the lowlands of Holland by windmills which are very numerous and work while the wind blows. Many farmers use windmills for pumping water for their live-stock and for their homes. The water is generally pumped into an elevated tank. From these tanks it is piped into the house for use in the various rooms and sometimes piped into the barn for the stock.



WINDMILL

In this way farmers enjoy the use and advantage of waterworks the same as the people in the city.

#### QUESTIONS AND EXERCISES

1. Where have you seen a natural waterfall or a dam? What practical use can be made of such places?
2. What use could a man make of a swiftly-flowing stream passing through his farm?
3. Make a water wheel and try it in some flowing water.
4. Make a small windmill and fasten it in some exposed position and observe how the wind affects it. What practical use is made of such machines?

## CHAPTER XXI

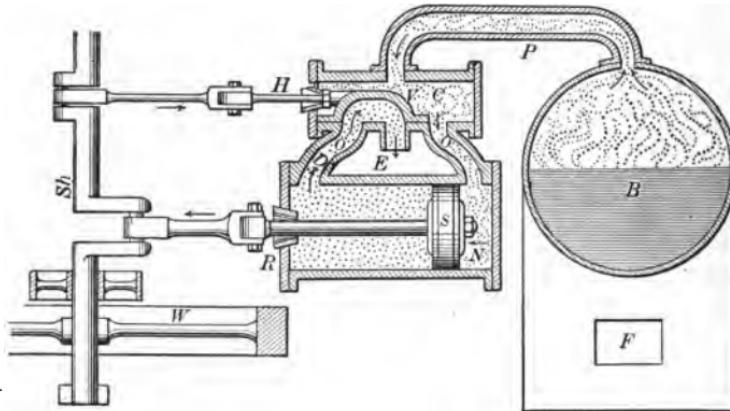
### STEAM AND GAS ENGINES

**138. Steam** is water vapor or water in gas form which has a temperature of  $100^{\circ}$  C. at standard pressure. When water changes to steam it increases in volume about 1,600 times, that is, one gallon of water will make 1,600 gallons of steam and fill a space of 214 cubic feet at standard pressure. The molecules of steam are very active and move about with high speed. The speed of the molecules varies with the temperature. To change water at boiling point to steam requires 536 calories for each gram of water, and the steam has the same temperature as the boiling water. These 536 calories of heat are used to make the molecules move faster. The faster they move the more space a given number of them requires and the harder they strike against the walls of the vessel enclosing them. Since the molecules of steam move at such a high speed they will rush with great force through any valve or opening that is made in the containing vessel. The energy of the steam is derived from the wood or coal which is oxidized to make heat.

**139. The Steam Engine.** — More than 150 years ago James Watt, an instrument maker living in England, studied the crude engines in use in his day and invented the double-action steam engine, which was the same in principle as the steam engines of the present time. Most of the improvements that have been made on Watt's invention have been on the machinery to which the engine

is attached, and of course many changes have been made in the mechanism of the engine itself, but there has been no change in principle.

The operation of a double-acting steam engine can be understood from the diagram shown in the illustration. The steam generated by the fire, *F*, in the boiler, *B*, passes through the pipe, *P*, into the steam chest, *C*, and thence through the passage, *O*, into the cylinder, *N*, where its



THE PARTS OF A STEAM ENGINE

pressure forces the piston, *S*, to the left. It can be seen from the diagram that, as the driving rod, *R*, moves toward the left, the eccentric rod, *H*, which controls the valve, *V*, moves toward the right. When the piston has reached the left end of its stroke, the passage *O* will have been closed, while the passage *D* will have been opened, thus permitting the steam to flow into the left end of the cylinder, which will force the piston to the right and force the spent steam on the right of the piston out through the exhaust pipe, *E*. The eccentric rod, *H*, moves the double valve in the steam chest, which opens and closes the passages *O* and *D* alternately at just the

proper moments to keep the piston moving back and forth throughout the length of the cylinder. The shaft, *Sh*, carries a heavy fly wheel, *W*, which, after being started, keeps the engine running at constant speed. The rotary motion of the shaft can be communicated to any desired machinery by means of cogwheels or of a belt which passes over a pulley securely fastened to the shaft.

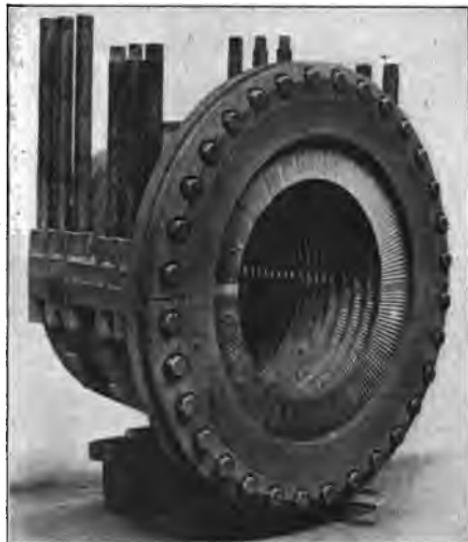
#### 140. Uses of the Steam Engine.—

Steam engines are classed according to use. Stationary engines do not move about and are used to operate factory machinery, run electric dynamos, etc. Traction engines are used for drawing

heavy loads through the country, for drawing gang plows and harvesters on the Western plains, for running threshing machines, etc. Street steam rollers are forms of traction engines. The railroad locomotive is a form of traction engine fitted to run only on steel rails. The power of ordinary traction engines varies from 10 to 20 horse power, while railroad locomotives vary from 500 to 1000 horse power.

#### 141. Steam Turbines.—

The steam turbine is a form of steam engine without back-and-forth motion such as



FIXED BLADES OF STEAM TURBINE ENGINE  
They direct the steam against the blades of the rotating shaft.

there is in the piston of the double-action engine. The principle of the steam turbine is the same as that of the water turbine or the wheel of a windmill. A wheel with a great number of blades like the wheel of a windmill is firmly fastened to a shaft; steam from nozzles is directed against the blades of the turbine wheel and the wheel is thus caused to rotate at a very high speed.



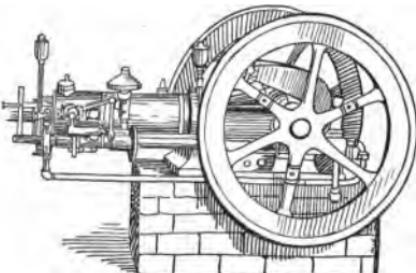
BLADES ON THE ROTATING SHAFT OF STEAM TURBINE

The steam enters at the middle, divides, and goes toward each end, causing the shaft to rotate at high speed.

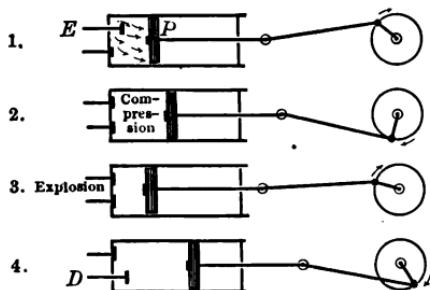
The steam can be used several times by allowing it to pass over the blades of several wheels which are set in series. Steam turbines are used where high speed and great power are needed, as on modern ocean vessels, the engines of some of which have 70,000 horse power. One of the Pittsburgh city water pumping stations has a steam turbine which runs a centrifugal pump that will throw 100,000,000 gallons of water in 24 hours.

**142. Gas Engines.** — In recent years gas engines have come into use for small power purposes and to a very great extent have taken the place of steam engines. Gas engines are driven by properly timed explosions by an electric spark, of a mixture of gas and air within the cylinder. A gas engine with a single cylinder has a heavy pair of fly wheels, because the piston receives energy

from exploding gas only at every other rotation of the fly wheels. The energy stored in the fly wheels by one explosion keeps the machinery running until another explosion. High power gas engines have two or more cylinders in which explosions occur alternately, thus the loss of power and speed between explosions is avoided. The best automobile engines have from six to twelve cylinders which insure a continuous supply of power and not by jerks as given by a single cylinder engine. The development and perfection of the gas engine have made the automobile a very effective machine and have also made it possible for aeroplanes to fly with considerable safety.



GAS ENGINE



PRINCIPLE OF THE GAS ENGINE

The diagrams illustrate the operation of one cylinder of a gas engine. In No. 1 a mixture of gas and air is being drawn into the cylinder through the valve as the piston, *P*, moves to the right. In No. 2 the valves are

closed, and the piston moving to the left compresses the mixed gases. In No. 3 just as the piston starts to move to the right an electric spark which ignites the gas is made in the cylinder, and an explosion results which drives the piston to the right with considerable force

and imparts its energy to the heavy fly wheel, which is set in rapid motion. In No. 4 as the motion of the fly wheel now drives the piston to the left, the exhaust valve, *D*, is automatically opened, and the spent gas escapes, making the characteristic noise of the gas engine. The next movement of the piston is the same as in No. 1, and the same cycle of motions is repeated.

**143. Efficiency of Engines.** — The mechanical efficiency of the gas engine is the highest of all heat engines, becoming as much as 25 per cent, which is nearly twice that of ordinary steam engines. The gas engine is free from smoke (the smoke made by some automobiles is due to the oxidation of an excess of lubricating oil in the cylinders) and can be started without delay, but the fuel is comparatively expensive.

The efficiency of the best steam engines is about 17 per cent, while the efficiency of locomotives is about 8 per cent, that is, only 8 per cent of the heat energy of the coal which is burned is transformed into mechanical energy by the locomotive while it is running. The efficiency of steam turbines is as high as that of the best double-acting engines. The advantages of the turbines are that they run smoothly, can develop high speed, and occupy only about one-tenth as much floor space as ordinary engines of the same power.

#### QUESTIONS AND EXERCISES

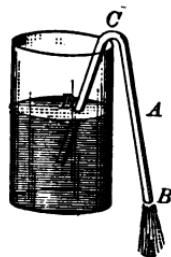
1. Can steam be seen? Is it heavier or lighter than air?
2. Who invented the steam engine? When?
3. Name the kinds of steam engines that you have seen.
4. What is the difference between a gas engine and a steam engine?
5. Where is the fire in a gas engine?
6. How does the gas engine get its power to run?

## CHAPTER XXII

### WATER OR LIQUID PUMPS

**144. Influence of Air in Pumping Liquids.** — Air has weight and each square inch of surface at sea level is holding up about 15 pounds of air, that is, the air exerts a pressure of 15 pounds per square inch; 15 pounds of pressure will sustain a column of mercury 30 inches high. Since mercury is 13.6 times as heavy as water, the air will sustain a column of water 34 feet high if there is no air pressure on top of the water. When the air is removed from a tube which is standing in water, the air pressure on the water outside the tube will force the water up the tube. When we drink a liquid through a straw, we remove the air pressure from the end which is in the mouth, and then the air pressing on the liquid in the vessel forces the liquid up the straw. But we could not drink water through a tube 35 feet high. Why?

**145. The Siphon.** — The siphon may be a U-shaped tube with the arm outside the liquid longer than the arm extending down into the liquid. The liquid in the tube is trying to flow in both directions from the point *C*. The liquid in *CD* is exerting a pressure on the liquid in the vessel, while the liquid in *CB* is exerting a downward pressure greater than that of *CD*, since it is longer than *CD* by *AB*. When two unequal forces resist each other there is

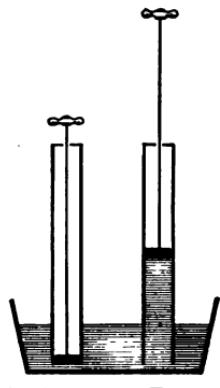


THE SIPHON

motion in the direction of the greater force. The air pressure at *B* is the same as the air pressure on the liquid in the vessel, so it is the difference between the downward pressure of the two columns of water in *CD* and *CB* that causes the water to flow. The liquid flowing from *C* to *B* tends to produce a vacuum at *C*, while the air pressure on the liquid in the vessel forces it up the tube *CD*; this process keeps the liquid flowing.

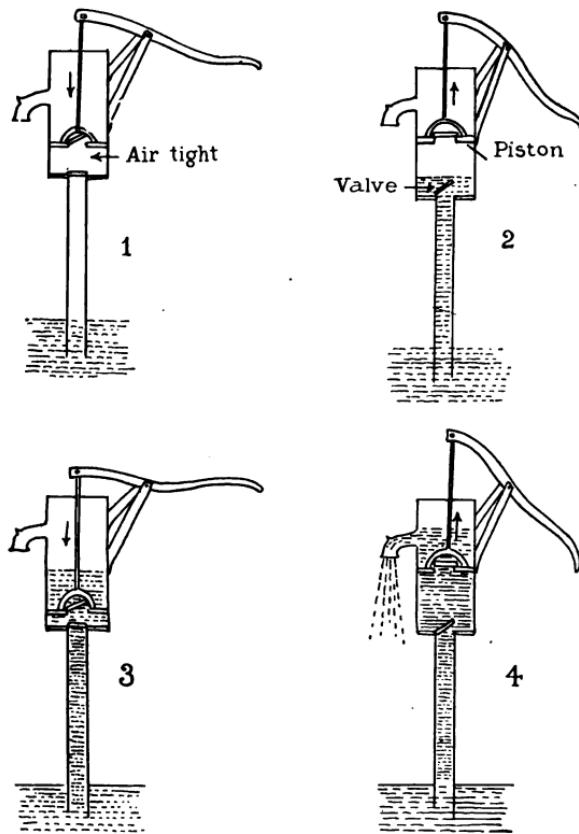
**146. The Common Lifting Pump.**—If one end of a tube containing a piston is placed in water and the piston drawn up quickly, the water will follow the piston up the tube. This occurs because the motion of the piston reduces the pressure on the water in the tube, and then the pressure of the air on the water outside the tube forces the water up the tube, the same as when we take lemonade through a straw by reducing the air pressure at the end of the straw in the mouth. If the piston in the tube in the illustration were pushed down, the water also would flow down. This return flow of the water is prevented in the common pump by placing valves in the tube. The valves open when the water flows up but close when it tries to flow down.

In common lifting pumps there is a valve in the piston and one in the pump tube as shown in the illustrations on page 215. When the piston moves down, the valve in it opens and the air escapes, as in diagram 1, while the valve in the pump tube was closed by its own weight and by the force of the air trying to pass through. In diagram 2 the piston is rising and the valve in it was closed by the



AIR PRESSURE FORCES  
THE WATER UP THE  
TUBE

air pressure; hence the air is prevented from getting back into the pump, while the air and water below the valve in the pump tube open the valve and fill the space below



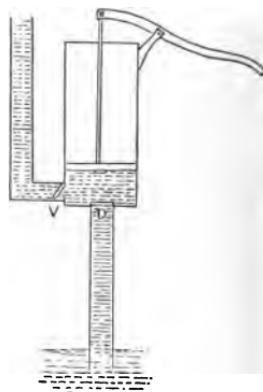
THE COMMON PUMP

the piston with air and water. In diagram 3 the valve in the pump tube closed to prevent the return of the water to the well, while the valve in the piston opened and allows the water to flow above it as the piston descends. At the next upward stroke of the piston the water will be

lifted out of the pump. The air pressure on the water in the well is what forces the water up through the first valve of the pump, but it will do this only when the air pressure in the pump is reduced by the upward movement of the piston. The piston must always be placed less than 34 feet from the surface of the water in a well.

Lift pumps are used in wells that are not very deep and in places where it is not desired to pump the water very far. The quantity of water thrown depends upon the size of the pump and the speed at which the piston moves up and down. The piston is usually placed down in the well far enough to prevent freezing.

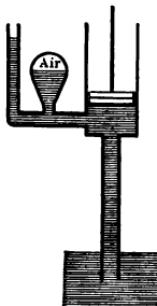
**147. The Force Pump.** — The top of a common lift pump is not water-tight, and so water cannot be raised any higher than the pump, even if a hose is placed on the pump spout. If the top were made water-tight, water could be forced through a hose attached to the spout, and the pump would then be a force pump. Force pumps are usually made so that the downward stroke of the piston forces the water out. This is done by placing the second valve in the side of the cylinder rather than in the piston. In the illustration, the valve *V* closes when the piston goes up, and the valve *D* opens to permit water to flow in from the well. When the piston descends the valve *D* is closed by the pressure of the water on it, and the valve *V* is forced open and the water flows out through the delivery pipe. The weight of the water in the delivery pipe closes the valve *V* when the piston



FORCE PUMP

ascends, so there is only an intermittent flow of water from the spout or hose attached to such a force pump.

In order to avoid this intermittent discharge and have a steady stream, an air dome or chamber must be attached to the delivery tube, as shown in the illustration. The downward movement of the piston forces water through the delivery tube and also into the air dome, because air can be easily compressed. (If air is compressed to one-third its original volume, it exerts a pressure three times as great as before.) So when the piston again ascends, the valve *V* closes, but the compressed air in the air dome



FORCE PUMP  
WITH AIR DOME



AIR DOMES OF HIGH PRESSURE PUMPS

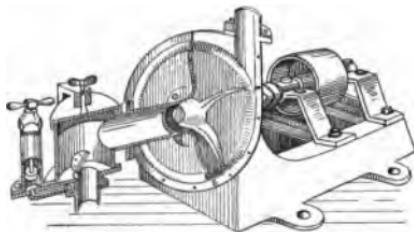
From photograph of those used for pumping the water to wash the sand of the filters of the Pittsburgh city water.

forces the water out of the delivery tube and keeps the stream of water flowing until the next downward stroke of the piston, when the dome is again filled. In this way a continuous flow is obtained. The size of the air

dome is determined by the size of the pump. The distance that water can be thrown depends upon the force applied to the piston.

Force pumps are often used in wells, and especially when a windmill is used as power for pumping. City fire engines which force water to the tops of high buildings use the force pump with a very large air dome. City water companies use high pressure force pumps to pump water into standpipes and hilltop reservoirs. Force pumps are also used for spraying fruit trees and other vegetation.

**148. The Centrifugal Pump** is a very modern type of pump without a piston or valve in the pump chamber.



THE PARTS OF A CENTRIFUGAL PUMP

It consists of a wheel enclosed in a strong metal case. The wheel is made to rotate very rapidly, and curved, spoke-like parts throw the water to the outer part of the wheel and case, and it is thus forced through the pipe or tube which leads from the case. As the wheel rotates rapidly a partial vacuum is produced in the case, and the air pressure on the water in the river or other source of supply forces the water through a tube to the center of the rotating wheel. The wheel forces it to the outer circumference of the case and out through the delivery tube.

The quantity of water delivered by such a pump is dependent upon the size and speed of the wheel. The centrifugal pump is not a high-pressure pump, and it is used only where it is not necessary to raise the water many feet and where a large quantity of water is desired.

Much of the water used for irrigating arid lands is elevated a few feet for that purpose by centrifugal pumps. When caissons of any kind are sunk in a river for construction work, such as the building of abutments for bridges or laying pipe lines across a river, the centrifugal pump is used to remove the water. Swamp lands also can easily be drained by this pump. Sand and other



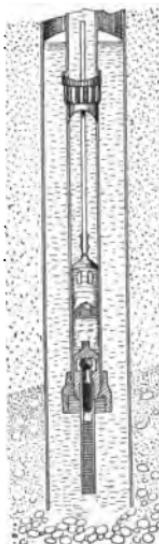
LARGEST CENTRIFUGAL PUMP IN THE WORLD

It can deliver 100,000,000 gallons in 24 hours. (Pittsburgh City Water.)

foreign matter do not injure the centrifugal pump as they do the valves of the force or lift-pump.

**149. Wells and How to Get Water from Them.** — Wells are sometimes made by digging a round hole about six feet in diameter and deep enough to reach sufficient water. The well is then walled with stone, leaving an opening in the center about three feet in diameter. The water usually comes from an underground stream called a vein. Wells sixty or more feet deep are drilled by machinery, and a large pipe casing is put down for the wall. Wells which are not very deep are usually drilled,

because this is not so expensive as digging. In sandy places where the water is known to be near the surface, sharp-pointed pipes with a number of small holes near the pointed end are driven down until they reach the water. A common pump is then put in the pipe and water can be obtained.



FORCE PUMP WITH  
PISTON IN WATER

In all wells the piston of the pump must be within 34 feet of the water, or the air pressure will not raise the water to the first valve. Since the valves cannot be made perfectly air-tight, the pump will work better if the piston is not more than 20 or 25 feet from the surface of the water. Force pumps are used in deep wells because the piston can be placed low and the water forced from the piston to the top. Even in a common lifting pump the piston is placed several feet down in the well in order to make it easier for the air to force the water up to it, and also to prevent freezing in winter. Freezing is prevented by opening a valve just above the piston, which permits the water above the piston to flow out of the tube. This valve must be closed again when one wants to pump water.

#### QUESTIONS AND EXERCISES

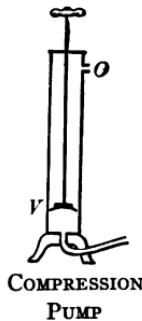
1. How does the air aid one in drinking a liquid through a straw?
2. Make a siphon of a rubber hose and explain the cause of the flow of the liquid.
3. Explain the difference between a common lifting pump and a force pump.
4. Why do high-pressure force pumps have air domes?
5. When ought you to install a centrifugal pump rather than a force pump?

## CHAPTER XXIII

### GAS PUMPS

**150. Gas Pumps** are used principally for pumping air. The structure of the gas pump is different from that of the liquid pump. The valves are different, and to be air-tight they must fit more accurately than to be merely water-tight. In cheap pumps the valves are usually made of leather and are kept soft and flexible by lubricating oil. Since the molecules of air are moving very rapidly, it will expand when the pressure on it is reduced. On this account air can be pumped into or out of a vessel. To pump air into a vessel the valve on the piston must be turned in the opposite direction from that in a pump that will force air out of a vessel; the former is called a compression pump and the latter an exhaust pump.

**151. The Compression Pump.** — The compression pump is one with which air can be compressed or forced into a vessel or bicycle tire. The diagram illustrates the action of a compression pump. When the piston is forced down, the valve *V* rubs against the side of the pump tube and prevents the air from escaping above or around the piston, and so the air is forced through the rubber tube into the tire. While the piston was going downward, the pump tube above the piston was being filled with air which passed in through the opening *O*. Some pumps permit the air to pass in through the opening around the piston bar. When the piston is drawn



upward, the valve in the tire closes and prevents the escape of the air from it. The valve *V* bends downward and allows the air above it to flow below the piston. This air is driven into the tire at the next downward stroke.

Compression pumps have a very wide commercial use. Every locomotive and street car has a compression pump which supplies the compressed air for the air-brakes; the self-opening and self-closing doors on electric cars are also moved in this way. Compression pumps are sometimes used for ventilating mines so that gases and impure air cannot collect in them; but two rotary fans are more often used for mine ventilation, similar to those used for ventilating large buildings and factories. One fan forces air into the mine and the other removes it. Compressed air drills used in stone quarries and compressed air riveters used in the construction of modern skyscrapers are very valuable commercial tools made possible by the compression pump.

The compression pump has made it possible for man to work under water. To illustrate how this is done, place a glass tube in water and blow into one end of it. As the air enters, the water moves out, showing that air can hold water out of a vessel when the vessel is immersed in water. A diving-bell large enough for men to work in can be sunk from a boat and air pumped into it to keep out the water; this air also supplies oxygen to the men. Excavations for bridge piers in deep water are sometimes made by sinking an air-tight caisson and then keeping the water out of the place where the men work by com-



AIR KEEPS  
WATER OUT  
OF THE TUBE

pressed air. Men can also work under water by using diving suits all made of rubber except the head protector, which is made of metal with transparent eyepieces. Some divers carry a tank of compressed air to breathe and others have air pumped to them through a tube.

Men cannot work under water very long because it is difficult to adjust themselves to the high pressure which is necessary to keep the water out. Divers scarcely ever work at a depth greater than 60 feet, and 80 feet or 90 feet is usually considered the limit of safety. But while building the bridge across the Mississippi at St. Louis, Missouri, the diving-bells with the workmen were sunk to a depth of 110 feet. A case is on record of a diver who sank to a depth of 201 feet while he was investigating a wreck off the coast of South America.

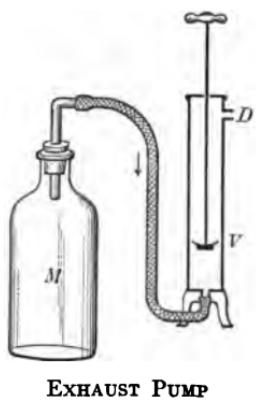
The diver experiences pain in his ears and above the eyes while he is descending and ascending, but he feels no pain when at rest. This is because it takes some time for the air to enter the interior parts of the body and establish a pressure on the inside equal to that on the outside.

**152. The Exhaust Pump.** — In the exhaust pump the valves are the reverse of those in the compression pump. Air can be pumped from a vessel because it will expand and fill the entire vessel regardless of how much air is in it. When the piston of the pump in the illustration moves upward, the air in the vessel *M*, to which the pump is attached, expands and fills the pump tube below the piston; at the same time the air above the piston is



DIVING SUIT

being forced out. When the piston moves downward the valve *D* closes and does not permit any air to enter, while the air below the piston passes around the piston valve *V* and fills the pump tube above the piston. At each upward stroke a pump full of rarefied air is taken from the vessel.



EXHAUST PUMP

The commercial use of the exhaust pump is not so extensive as that of the compression pump, although very necessary. Electric light bulbs have the air removed so that oxygen cannot burn the filament. Thermos bottles have the air removed from between the two glass bottles so that heat cannot pass out by conduction or convection.

**153. Pneumatic Dispatch Tubes** used in department stores, railroad stations, and in many cities for sending mail, have an exhaust pump at one end to remove air from the tube. The articles sent through the tubes are placed in leather cases which fit tight in the metal tube so that the air cannot pass around them. The exhaust pump removes the air pressure from in front of the leather case, and the compressed air behind it forces the case rapidly through the tube.

#### QUESTIONS AND EXERCISES

1. Take the valve out of a bicycle pump and explain its action.
2. Is the bicycle pump a compression pump or a force pump?
3. How does a compression pump differ from an exhaust pump?
4. What practical use is made of both kinds of pumps?
5. Which kind do you think is used more extensively?

## CHAPTER XXIV

### CITY WATER SUPPLY

**154. The Problem of Pure Water.** — The problem of supplying rapidly growing American cities with water is not an easy one and to supply pure water is much more difficult. The city of New York has spent many millions of dollars to bring a supply of pure water from the Catskill Mountains. Pittsburgh has one filtering plant that covers 60 acres and has spent a large sum during the last ten years to get pure water. Many other cities are doing the same. The world has awakened to the necessity of pure water, principally because of the large number of epidemics of typhoid fever which have been caused by contaminated water. Typhoid fever germs live in the food tube of the body and the excreta of a typhoid patient contain large numbers of such germs. In a city with a system of sewage such germs might pass from the sewers into a river without being killed. Some cities and towns take their water directly from rivers, at times not far below another large city. Such cities will get many germs in their water supply. Other cities—as Buffalo and Cleveland—take their water from lakes into which their own sewage flows. Many cities which drain their sewage into rivers and lakes now have a means of disposing of the sewage in such a way as to render it harmless to their neighbor cities. Filtering river water by passing it through settling basins and sand filters and adding chemicals removes about 98 per cent of the germs. The

comparative results of drinking unfiltered and filtered water in four of our American cities is shown graphically in the diagram below.

**155. Methods of Purifying Water.** — (a) *Boiling* the water will kill the germs in it but will not take out any impurities. Water must be clean enough to drink before boiling, except for a few living germs, or it will not be fit for drinking after boiling. The destruction of germs by boiling is practicable only in private homes. It would be too expensive for the city water supply.

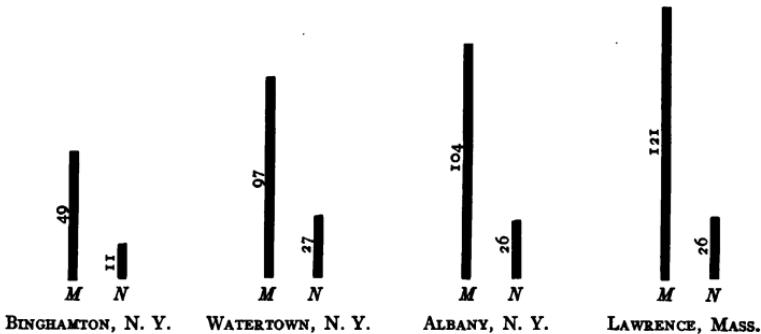


DIAGRAM SHOWING HOW SUPPLYING A CITY WITH GOOD WATER  
LESSENS SICKNESS AND DEATH

The lines *M* above each city show the relative number of persons dying of typhoid fever before the water was filtered. The lines *N* show the number dying after the water was filtered. The figures are the number of deaths from typhoid occurring out of 100,000 inhabitants.

(b) *Distilling* is the most effective method of purification. It removes from the water not only disease germs but also many other impurities, such as dissolved salts. Artificial ice is made of distilled water and hence it is free from germs. But distillation would be a very expensive method of purifying water for cities.

(c) *Filtering* with the aid of a few chemicals is the method used for purifying city water. The filter bed is

made of two or three feet of fine sand spread on top of a foot or two of coarse sand and gravel, with stones at the bottom. As the water soaks through the sand the solid matter — the impurities — are left on top of the filter bed. The filter bed is underlaid with piping full of holes to receive the filtered water.



INTERIOR OF FILTERING PLANT

Showing the instruments for operating each filter. (Penn'a Water Co.)

In the slow filtering process the water is pumped to a settling basin in which the heavy sediment sinks to the bottom. From the settling basin it is permitted to flow slowly on the filter beds. For a large city there must be several acres of filter beds. From the filters the water flows into a storage basin where enough chemicals are added to kill the disease germs.

In the rapid filtering process the water is pumped from the river to the top of a high hill where the filtering plant is located. The amount of chemicals

necessary to precipitate solid matter and kill bacteria and germs is put into the water just before it pours from the pump delivery pipes into the settling basin. From the settling basin it flows over the filter beds, which are about 20 feet long and 18 feet wide. Each filter bed will remove the solid matter and dead germs from about 1,000,000 gallons in 24 hours. These filter beds are washed once every 24 hours by forcing water through them in the opposite direction from that in which the filtering water flows through.

**156. Methods of Supplying Water.** — Cities have various methods of supplying sufficient water for their needs, depending upon their location with regard to streams, lakes, and mountains. There are three systems in use.

(A) *Gravity System.* — Cities that are located near mountains have the water piped from lakes or streams that have an elevation much greater than that of the cities. In this way great pressure is secured for the entire city, and the water will flow with considerable force from any faucet. The water flows to the city because of its own weight. Denver, Colorado, uses the gravity system by having the water piped from the mountain streams. Los Angeles, California, is using this system in part. The water from the mountains is usually pure enough so that it does not need to be filtered, and the expense of both pumping and filtering is avoided.

(B) *The Pumping System* is used extensively by small cities along rivers and in those parts of the country in which there are no elevations or hills upon which to place reservoirs or stand pipes. In some Western cities the water is filtered and then pumped through the main pipe lines into the houses. In certain cities along the Ohio River the water is pumped directly into the houses with-

out being filtered. The speed of the pumps is determined by the pressure of the water in the main pipes. When a great number of people are using water the pressure in the pipes is slightly reduced and the pumps then increase their speed, thus keeping the pressure about constant.

(C) *Combination of the Pumping and Gravity Systems.*—Cities located in hilly parts of the country use the tops of some of the hills for storage reservoirs for water. Standpipes also are usually located on some high point. The water is pumped from wells or rivers into these reservoirs or standpipes



FILTERING PLANT AND STANDPIPE  
Containing air and water for washing the filters. (Penn'a Water Co.)



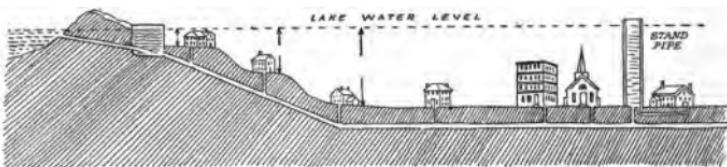
SETTLING BASIN

Water coming from the river 560 feet below. The chemicals are added before the water comes out of these fountains. (Penn'a Water Co.)

and then it is permitted to flow through the mains into the houses by the force of its weight or gravity; thus

the pumps force it to the reservoirs and gravity delivers it to the houses. New York City uses gravity to deliver the water from the Catskills, but after reaching the city the water has to be pumped in order to have sufficient pressure.

**157. Why Water Pressure is not Uniform.** — Before city reservoirs and standpipes are constructed, it is

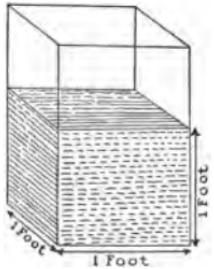


RESERVOIR AND STANDPIPE

Standpipes used with the reservoir to keep a constant pressure at a distance from the reservoir.

necessary to ascertain the quantity of water needed in order to determine how strong to make the walls of the reservoirs and standpipes. The greater the height at which the water stands, the thicker the walls must be.

The greater the elevation of the houses that use the water, the stronger must be the pumps and the stronger must be the walls of the standpipe to resist the pressure.



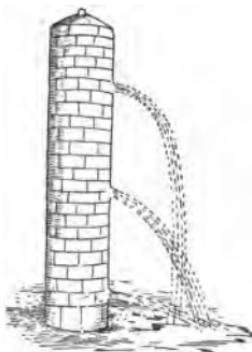
CUBIC FOOT

Cubic foot of water weighs 62.5 pounds.

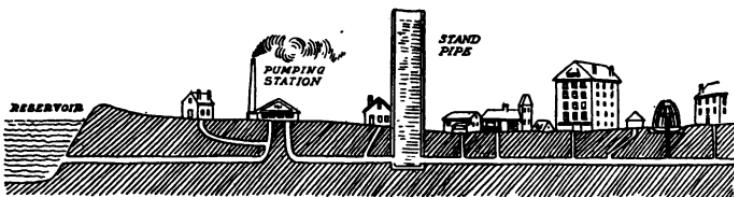
At  $0^{\circ}$  C. weighs about 62.5 pounds; that is, when water is one foot deep it presses down 62.5 pounds on every square foot, or .434 of a pound on each square inch; or

the pressure is .434 of a pound per square inch for each foot in depth. If the water is 10 feet deep the pressure is  $.434 \times 10$ , or 4.34 pounds per square inch; if it is 30 feet deep the pressure is 13.02 pounds per square inch on the bottom of the vessel or reservoir. Standpipes 100 feet high full of water have a pressure of 43.4 pounds per square inch at the bottom.

The pressure against the side of the standpipe near the bottom is almost the same as the pressure on the bottom. The pressure against the side of the standpipe halfway up is half the pressure at the bottom. If the standpipe were tapped at the bottom and also halfway up from the bottom, the water would flow out with a force twice as great at the bottom as it would at the upper spout. If the standpipe is only half



HEIGHT OF WATER DETERMINES THE PRESSURE



PUMPING SYSTEM

Used in level countries, assisted by standpipes.

full, the water pressure at the bottom is only one-half as great as when it is full to the top. From this we see that if the height of the water in the standpipe varies, the pressure in the pipes leading from it to the houses will

also vary. As the height of water in the reservoir changes, the pressure in the houses will also change.

Water pressure is also reduced by the friction of the flow of the water through the pipes, joints, and valves. Again, if many people are using water at the same time, the pressure will be lessened because the pipes are not usually large enough to carry a full pressure supply for all at the same time. So the three conditions upon which water pressure is dependent are the height of water in the reservoir, friction in the pipes, and the number of people using water at one time. If several people on the first floor of a building are drawing water, those on the upper floors may not get any, as the pipes in the basement are not usually large enough to carry sufficient water to make it flow from all the faucets at the same time.

**158. Equal Pressure.** — Large cities try to meet the difficulties discussed in § 157 by having reservoirs on various hilltops; or if hills are not sufficiently numerous, standpipes are erected at various distances from the reservoir, or pumping station. If there are a number of reservoirs, the friction caused by water flowing through long pipes is avoided and a more constant pressure and supply are secured. If the reservoir and standpipe system is used, the water flows from the reservoir into the standpipe when not many people are drawing water. During the hours when a large quantity of water is needed, it flows from the standpipe because the distance of flow is less and hence the friction is not so great as when the water flows from the distant reservoir. Standpipes are also often combined with the pumping system in order to insure normal pressure in the parts of the city which are distant from the pumping station.

**159. The Cost of City Water.**—Families may have to pay from one dollar to ten dollars per year for water. This is not very much per gallon, but when the total cost of a large city is ascertained it amounts to millions of dollars. Where the gravity system is used the cost is very small, as not much work is needed after the pipes are once laid. But where the cities are in a level country, or where the source of water is no higher than the city, the cost of water is greater because of the necessity of pumping it and often of purifying it.

To get some idea of the work done in pumping water for a city, let us consider the Pennsylvania Water Co., which supplies water to about 30,000 people, principally in Wilkinsburg, Pa. A gallon of water weighs approximately 8.3 pounds. The work done by a pump in raising a gallon of water 560 feet to the filtering plant is  $8.3 \times 560$ , or 4,648 foot pounds. The company pumps 8,000,000 gallons every 24 hours, and the work done in raising it to the filtering plant is  $8.3 \times 560 \times 8,000,000$ , or 37,184,000,000 foot pounds. The work that can be done by one horse power in 24 hours is  $550 \times 60 \times 60 \times 24$ , or 47,520,000 foot pounds. So the number of horse power required to pump that water is approximately  $37,184,000,000 \div 47,520,000$ , or 782 H. P. An engine of about 1,000 H. P. would be required to pump the 8,000,000 gallons per day up to the filtering plant. After the water is filtered, it is distributed by the force of gravity to the various houses in the valley below.

**160. Water Supply and Forests.**—There are two causes which influence the maximum flood stage of most streams.

*First:* The highest floods usually come when a heavy snow is melted by a warm rain during the winter or early

spring. Now as a rule forests give the snow some protection from the direct rays of the sun and so delay its melting; but this snow will go off rapidly when a warm rainy season comes. The snow water and rain usually give the river channels more water than they can carry and a flood results. Where there are no forests the snow on the southern slopes is usually melted by the direct rays of the sun, and the water from it is gone and out of the way before the snow on the northern slopes is melted directly by the sun or by warm rains. The snow on the eastern and western slopes will melt gradually between the melting of that on the southern and northern slopes where there is no forest. A flood caused by the melting of snow by rain is general and affects the large rivers as well as the small streams. This first cause is in favor of the deforested region or sections and against the forests.

*Second.* The second cause is in favor of the forested regions. By careless methods of agriculture many deforested fields and slopes are unprotected by any kind of vegetation. This bare, wornout soil, having lost its ability to receive and retain water because of the loss of its humus, does not permit much of the water to soak down into it, and so the water rushes rapidly down the slopes and into the larger streams, carrying a large quantity of sediment, clay, sand, and rock. The larger creeks that do not flow so rapidly are not able to transport the heavy load of solid matter delivered to them, and so their beds become choked with gravel and rock. A creek bed almost full of sediment does not require much water to fill it, and the result is that the excess of water during a rainy season is spread over the valley on either side. These creeks during their flood stages deliver more sediment to the rivers than they are able to move along,

and their beds become filled. The levees along the Ohio and Mississippi must be continually raised in order to keep the water within the river banks. The bed of the Mississippi is in many places higher than the country on either side; hence when the water breaks through its levee much damage is done.

If our rural population would learn how to keep the cleared fields covered with vegetation and the soil supplied with the proper amount of humus, this cause of floods would be removed, and there would be less need of the forests so far as the control of water supply is concerned. There are, however, many good reasons why there should be forest regions and wooded slopes.

The soil in the woods during a long dry season is much dryer than the soil in a properly cultivated field. A grass field is also much dryer than a field under cultivation. The reason is that the roots of the trees absorb the water from the soil rapidly and it is transported to the leaves, which give it to the air by evaporation. Water from the deeper parts of the earth gradually works its way to the surface during a dry season, but the roots of the trees absorb it as fast as it comes by capillarity toward the surface. In a cultivated field where crops are growing, the leaf surface of the plants is not nearly so great as the area of all the leaves on the trees in the woods, and for this reason there is not so much water given off by evaporation by the cultivated crop as there is by the forest trees. Evaporation from the bare soil is also prevented by stirring the surface of the soil and producing what is known as dust mulch. Farmers who have not learned how to conserve soil moisture during dry seasons do not have much success in agriculture.

From this comparison it can easily be seen that during

a dry season there will be more water to flow into the creeks or rivers from properly cultivated fields than from forested regions, and when rain comes the cultivated fields will be moistened sooner than the forested parts and so the streams will again receive water from the cultivated fields before they will from the woods.

There is practically no effect upon the rainfall, floods, or water supply when a forested region is changed to a properly cultivated agricultural section. Careless farming, of course, results in the loss of much that is useful.

#### QUESTIONS AND EXERCISES

1. What is the source of water for your home? Is it free from typhoid or other disease germs?
2. How do you purify your drinking water? Do you use the best method?
3. Make a careful study of water supply of your town or city in order to learn if any dangerous chemicals or disease germs are in it.
4. What can you do to help get purer water?
5. What method is used to get the water into your home?
6. Does the water always flow with the same force? Why?
7. If a reservoir is 150 feet higher than your home, what is the water pressure at the spickets?
8. Determine the cost per gallon of water which you use.  
(Obtain the necessary facts from your water company.)
9. How do forests affect the water supply of your locality?
10. Visit some creeks to see if they have been affected by the removal of the forests.
11. How can farmers remedy the bad effects which come from the removal of forests?

## CHAPTER XXV

### MAGNETS

**161. Natural Magnet or Lodestone.** — The ancients found a certain hard, black stone at Magnesia, in Asia Minor, which they called a magnet. It had the property of attracting small pieces of iron. They thought that the stone possessed some magic property and it became very famous. It was not discovered until about the eleventh century that the famous magnet-stone would take a north and south position when it was hung up by a string. This property of the stone enabled men to determine direction by its aid, hence it became useful in navigation. From such uses of the stone it received the name lodestone or "leading-stone." The natural magnet is an iron ore called magnetite, which has the chemical composition  $\text{Fe}_3\text{O}_4$ , an iron oxide. The ore is found in quantities in Sweden, Spain, Arkansas, and other parts of the world, but not always in a magnetic condition.

**162. Artificial Magnet.** — If a lodestone is rubbed over a piece of hard iron, the iron will become magnetized so that it will attract particles of iron in the same way as the lodestone. The magnetized iron will also take a north and south position when it is suspended by a thread. As early as 1729 it was learned that steel will hold magnetism much longer than iron.

The illustration shows that the iron filings adhere in a mass at the ends of the magnet instead of covering

it. The strings of filings at one end all point to the same part of the magnet. The parts to which the filings point are the poles of the magnet.

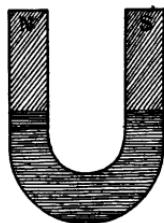


AN ARTIFICIAL MAGNET

After being dipped in iron filings.

The magnetic force is greatest at the poles and decreases to zero toward the middle of the magnet. The middle, where there is no attraction, is called the equator, and the line joining the two poles is called the axis of the magnet. In a horseshoe magnet the equator is at the curved part, the poles at the two ends, and the axis is a straight line joining the two poles. When a magnet is suspended so that it can swing freely, the end pointing north is called the north-seeking pole, or simply the north pole, and is marked *N* on the magnet; the other end is called the south seeking, or south pole, and is indicated by *S*.

A *compass* is a magnetized steel bar balanced on a pointed support so that it can swing freely without much friction. It is shaped so that one can tell easily in what direction it points, that is, tell in what direction the axis



A HORSESHOE  
MAGNET

stands. When a compass needle is free to turn, it will stand with its axis parallel to the magnetic meridian. The compass box has the directions and degrees marked so that it is easy to tell the different directions.

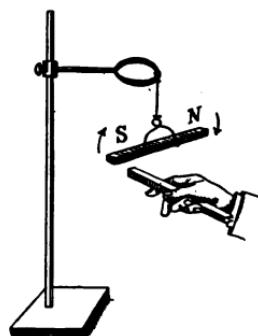
### 163. Magnetic Attraction and Repulsion.

— There is no visible difference in the way the two ends of a bar magnet attract iron filings. But there is a difference in the two poles, which can be seen by presenting them successively to the same end of a magnetic needle. One



A BAR MAGNET  
MADE OF STEEL

end of the magnet attracts the needle and the other end repels it. The pole of the magnet which repels the north pole of the needle attracts the south pole, and the pole of the magnet which attracts the north pole of the needle repels the south pole. From this we conclude that the north-seeking ends of magnets repel each other and a north-seeking end and a south-seeking end attract each other, that is, *magnetic poles of like kind repel each other and poles of unlike kind attract each other.*



MAGNETIC ATTRACTION  
AND REPULSION

**164. Nature of Magnets.** — No magnet can be made with only one pole. If a magnet is broken, each piece will have two poles of opposite kind. The poles that appear near the point of breaking are of opposite kind, one an *N* pole, the other an *S* pole. This subdivision may be continued indefinitely, but two opposite poles will appear at each break.



WHEN A MAGNET IS BROKEN UNLIKE POLES  
APPEAR AT THE BROKEN ENDS

subdivision may be continued indefinitely, but two opposite poles will appear at each break.

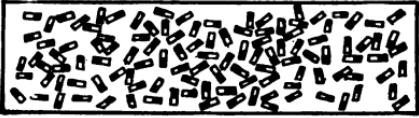
If several bar magnets are laid so that opposite poles touch, the whole line of magnets will act as one magnet and only two poles will be manifested, one at each end. Iron filings will adhere in quantity only around these two poles. The results obtained by breaking a magnet, and by placing



A SERIES OF MAGNETS ACT AS ONE MAGNET

several magnets with opposite poles together, suggest that the molecules of which the iron is composed are small magnets. When all the molecules of a steel bar

are so arranged that the *N* pole of one molecule is in contact with the *S* pole of the next molecule, and so on through the entire bar of steel, then all

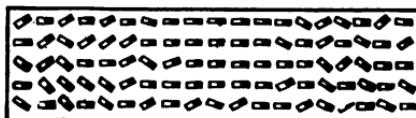


ARRANGEMENT OF MOLECULES IN UNMAGNETIZED IRON OR STEEL

the molecules at one end of the bar would have their *N* poles exposed and the molecules at the other end would have their *S* poles exposed. By jarring or heating a magnet the molecules are so disturbed that their alignment is broken and they arrange themselves in groups and short chains until no magnetism is left. When a steel bar is being magnetized, the molecules are being drawn into alignment so that opposite poles of the molecules touch one another. If a steel bar is being magnetized, jarring it while between two poles of a magnet will assist in causing the molecules to take the proper arrangement. Soft iron is easily magnetized, but it does not retain the magnetism like a steel bar.

**165. Induced Magnetism.** — If a tack or a small nail is suspended from the end of a bar magnet, a second tack can be hung to the first and

a third to the second, because each tack acts as a magnet and holds the one next below it. If the upper tack is carefully removed from the bar magnet, all the other



ARRANGEMENT OF MOLECULES IN MAGNETIZED IRON OR STEEL

tacks will drop from the first one, since they do not retain the magnetism, and act as magnets only while in the presence of the bar magnet from which they obtained their force. Any piece of soft iron may be thus magnetized temporarily by holding it in contact with a permanent magnet; but actual contact is not even necessary. Present



INDUCED MAGNETISM WITH AND WITHOUT CONTACT

some iron filings to one end of a soft iron nail while a magnet is held near the other end of the nail. It will be found that the nail will act as a magnet and hold some of the filings. Now lay a piece of glass on some filings or tacks and touch the glass with the end of a good bar magnet, then lift the magnet and glass and see how many tacks are held to the glass by the magnet. Remove the magnet from the glass and the tacks will drop. Several sheets of paper may be used in place of glass and the result will be the same. *Magnetism produced by such methods, with or without contact, is called induced magnetism.*

When a nail is near a magnet, it becomes a magnet by induction. If the *N* pole of a magnet is placed near a nail, the end of the nail near the magnet becomes an *S* pole and the other end of the nail becomes an *N* pole. The magnet will then pick up the nail, because two unlike poles attract each other. (See the law of

magnets.) The particles of iron filings become magnets by induction also when in the field of a magnet. The *N* pole of one particle attracts the *S* pole of the particle



SUCCESSIONAL MAGNETIC INDUCTION

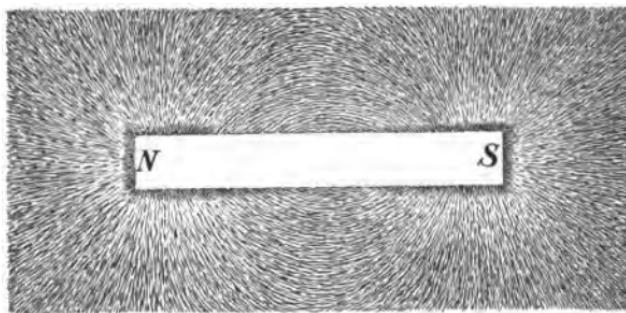
next to the first and so on out from the magnet until a whole string of iron filings is formed. Since like poles repel one another, the outer ends of these strings of iron filings will have a brushlike appearance; the ends of the strings being all of the same pole shove one another apart.

**166. Magnetic Field about a Magnet.**—The space around a magnet which is affected by its force is called



THE COMPASS FOLLOWS THE LINES OF FORCE OF A MAGNET

the magnetic field of the magnet. This field is most intense near the poles of the magnet and decreases in strength as it recedes from the poles. At every point in a magnetic field the force has a particular strength and acts in a certain direction. If a very small compass is placed on the side of a bar magnet near the N pole and then moved in the direction in which the needle of the compass points, it will be found that the compass will take a curved path

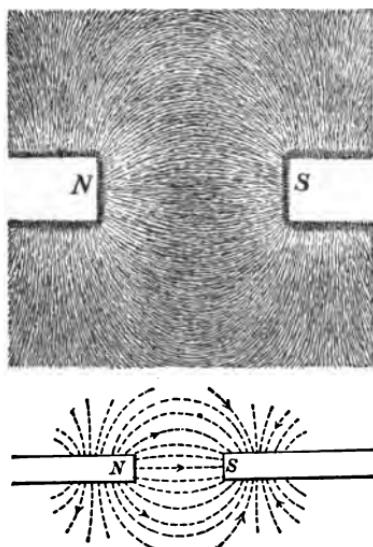


FIELD ABOUT A MAGNET

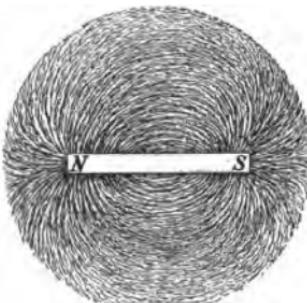
toward the S pole of the magnet. In this way the whole magnetic field may be mapped out. Each of the lines

thus mapped out is called a line of force. These lines of force about a good magnet are very numerous.

A convenient way of studying the field around a magnet is to place the magnet under a piece of paper covered with iron filings. The filings will form curves joining the *N* and *S* poles of a bar magnet, and some lines will go out from each pole which do not seem to join one another. If a horseshoe magnet is used, we find lines of force going straight across from the *N* pole to the *S* pole and also lines going in the opposite direction.



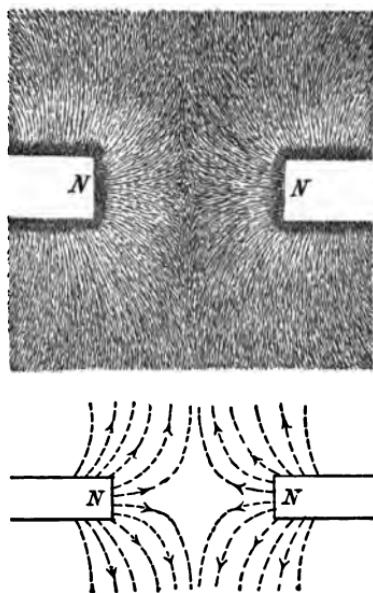
FIELD ABOUT N AND S POLES OF TWO MAGNETS, SHOWING LINES OF ATTRACTION



IRON FILINGS SHOW THE FIELD ABOUT A MAGNET

If opposite poles, *N* and *S*, of two bar magnets are placed near each other under a piece of paper on which iron filings are sprinkled, it will be found that lines of force join the two magnets much the same as the lines joined the two poles of the same magnet. Now reverse one of the two magnets so that an *N* pole is near an *N* pole, and sprinkle iron filings over the paper again. Observe that lines of force do not

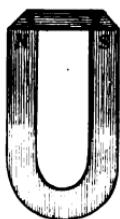
pass from one pole to the other, but that the iron filings are forced apart. Does this agree with the law of magnets?



SHOWING LINES OF REPULSION OF TWO LIKE POLES OF MAGNETS

have their opposite poles connected by an iron conductor, called an armature. This iron becomes a magnet by induction and the magnetic

lines of force pass through it. Magnets should not be jarred or heated as both tend to remove the alignment of the molecules and thus destroy their magnetism. Like poles of two good magnets should not be placed very near each



HOW TO KEEP A HORSESHOE MAGNET



HOW TO KEEP TWO BAR MAGNETS

### 167. Care of Magnets.

— If four bar magnets are laid in the form of a square so that opposite poles, N and S, are touching, a complete circuit for the lines of force will be formed by the magnets and there will be no external magnetic effect. (This can be proved by touching them at various places with a nail or by use of iron filings.) This shows that the steel of magnets conducts magnetic lines of force better than air.

For this reason, magnets while not in use should

other, and especially not in contact, because the stronger of the two will weaken, reverse, or completely destroy the magnetism of the other, or else make secondary poles.

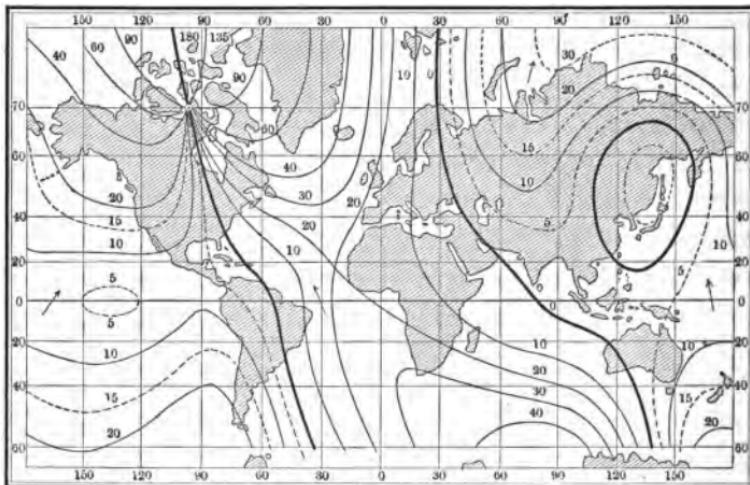
**168. How to Magnetize Steel.** — The simplest method of magnetizing a small piece of steel is to draw the steel slowly across one end of a magnet. The end of the steel leaving the magnet will have a pole opposite that of the end of the magnet across which the steel was drawn. The second method is to lay the steel on the table and take a bar magnet in each hand and touch opposite poles, *N* and *S*, together on the middle of the piece of steel and then slowly draw the magnets apart toward the ends of the piece of steel.



**169. The Earth a Magnet.** — We have learned that magnets attract each other if unlike poles are placed near together, and repel each other if like poles are placed near together, and that magnets do not attract or repel objects which are not magnets or which cannot be made magnets by induction, that is, magnets do not attract or repel glass, paper, and similar substances. Hence we may say that magnets only attract or repel poles of magnets or poles of substances which are made temporary magnets by induction. This being true, there must be a magnetic pole somewhere in the north which attracts one pole of a balanced magnet, such as a compass needle, and repels the other pole, which in turn is attracted by a magnetic pole somewhere near the south geographic pole.

We have also found that the needle of a small compass places itself parallel with the lines of force coming from the *N* pole and going to the *S* pole of a bar magnet. Since a compass acts on the earth the same as it does

when in the field of a magnet, the earth itself must be a magnet with an *N* pole and an *S* pole. Since the lines of force passing from one magnetic pole of the earth to the other are so weak, their effect on the compass is easily overcome by the strong field around a bar magnet.



MAGNETIC MERIDIANS  
Showing lines of equal declination.

And yet the earth's lines of force are strong enough to move the needle of the compass in a north and south direction when no other magnet is near.

The magnetic poles of the earth are not exactly at the geographical north and south poles. The magnetic north pole of the earth is more than 1000 miles away from the actual pole, being in latitude  $70^{\circ} 5'$  north, and longitude  $96^{\circ} 46'$  west. It was located in 1831 by Mr. Ross. It is just within the Arctic Circle in Boothia Felix. The south magnetic pole of the earth has never been located. Because of the irregularities in the distribution of the magnetism, there seem to be two south magnetic polar regions.

Since the magnetic north pole is not at the actual north pole, a compass does not point directly north in the United States except on one line. This line comes south from the magnetic pole and passes through central Ohio and thence turns slightly toward the southeast. A compass anywhere on this line points due north, but a compass east of the line points west of true north, and one west of the line points east of true north. At New York the compass points about 9 degrees west of true north, at Pittsburgh about 3 degrees west of true north, and at San Francisco about  $16\frac{3}{4}$  degrees east of true north. This variation of the compass is called declination. The declination of the compass gave Columbus trouble when he crossed the Atlantic the first time. Mariners now have charts showing the declination for all parts of the earth. The declination of the compass at any one place changes slightly from one season to another, but it makes greater changes during a period of years. From 1580 to 1816 the declination at London changed from  $11^{\circ} 17'$  east to  $24^{\circ} 30'$  west, making a total change of  $35^{\circ} 47'$  during a period of 236 years.

#### QUESTIONS AND EXERCISES

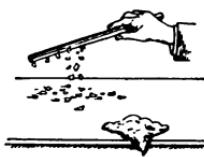
1. What is the history of lodestone?
2. How can you magnetize your knife blade?
3. Why does a suspended magnet point north?
4. Does a magnet point due north where you are? Why?
5. Test the law of magnets by having one magnet suspended and bring near its poles the poles of another magnet.
6. How does a magnet pick up a tack?
7. With a small compass trace some lines of force about a bar magnet.
8. How do you care for your magnets? Why?
9. If the earth were not a magnet, would a compass be of any value in determining directions? Why?

## CHAPTER XXVI

### SIMPLE ELECTRICAL APPLIANCES AND MACHINES

**170. Electricity** is the name given to an invisible agent known to us only by the effects which it produces and by various manifestations called electrical. These manifestations, a few centuries ago, were obscure and even mysterious, but they are now comparatively well known to the majority of people. However, the exact nature of electricity is not yet sufficiently understood even by the greatest scientists.

**171. Electrification by Friction.** — If a piece of hard rubber or a stick of sealing wax is rubbed with flannel or cat's fur and then brought near some dry bits of paper



ELECTRIFICATION BY  
FRICTION

The bits of paper jump to and from the glass rod which has a positive charge.

The bits of paper jump to and from the glass rod which has a positive charge.

or pith balls, these light bodies will jump toward the rod. As early as 600 B.C. the Greeks discovered that rubbed amber had such characteristics. Dr. William Gelbert, the father of modern science, in A.D. 1600 was the first to discover that these same electrical effects could be produced by rubbing together a great variety of other substances besides amber and

silk; such, for example, as glass and silk, sealing wax and flannel, hard rubber and cat's fur, or even by rubbing the hand on sheets of paper.

The electrical charges produced on these objects by friction have a peculiar relation much like the north-

seeking and south-seeking poles of magnets where like poles repel and unlike poles attract each other. The electrifications which are imparted to glass by rubbing it with silk and to sealing wax by rubbing it with flannel are opposite in the sense that an electrified body that is attracted by one is repelled by the other. We have, therefore, two kinds of electrification, and for convenience we call one positive and the other negative. Positive electricity is like that on glass when rubbed with silk, and negative electricity like that on the sealing wax when rubbed with flannel. We also have a law much like that applied to magnets, namely, *electrical charges of like kind repel each other, while electrical charges of unlike kind attract each other.*

**172. Lightning Rods.** — Benjamin Franklin was the first to prove that lightning and electricity are the same. During a thunder storm he sent up a kite which had a sharp-pointed wire on the top to receive or discharge electricity. He used a hempen string which became a conductor after it was wet. He held it with a silk handkerchief, a non-conductor, so that he would not receive a shock. From the metal key which was tied to the hempen string near him, he was able to draw electric sparks. This suggested to him that the electric charge in the cloud could be neutralized by setting up a number of sharp-pointed rods which would permit the induced charge on the earth to escape into the air. The charged particles of air would be drawn to the charge in the cloud since they were of the opposite sign.

Lightning rods made of good conducting material, placed deep enough in the ground to reach damp earth (for dry earth is a poor conductor), and provided with good steel points on the top of the building, will neutralize

the heavy charge in an approaching cloud by sending off a continuous stream of charged particles of air. If a lightning rod is not a good conductor the induced charge on the building may become so great that it attracts the charge in the cloud. The spark coming from the cloud, being very large, will then suddenly rush to the ground over the lightning rod and may melt the rod and set fire to the building.

There is no need of being afraid during an electric storm. It is no safer in a closet or a darkened room than it is in daylight or in a well-lighted room. Usually the safest place during a thunder shower is near the middle of a room. To get under a tree standing in an open field is of course dangerous, because the tree is the only tall object around. If a flash comes in that direction the tree will be apt to conduct it to the ground. It is not so dangerous to stand under trees in the woods where there are many trees as it is to stand under one tree in an open field during a thunder shower.

**173. Current Electricity.** — To understand what makes the electric current flow, let us use what we learned about temperature and the flow of liquids. Heat will flow from an object with a high temperature to an object of low temperature regardless of the quantity of heat in either. If two objects of different temperature are placed together, the cooler one will receive heat from the warmer one. In the case of liquids, water will flow from a high vessel into a low one if they are connected by a tube, even though the low vessel may have ten times as much water in it as the higher one. The water in the high vessel has a greater downward pressure than the water in the low vessel, hence the flow is in the direction

of the greatest pressure, or the difference in pressure is the cause of the flow.

The electric current is caused by the difference in electrical pressure at the two ends of a conductor. *This difference of electrical pressure is called potential.* (Potential means *to be able*, or *to have power*.) Electricity flows from high potential to low potential. High potential is positive and low potential is negative, so another way to designate the direction of flow of electricity is from positive to negative. These, however, are terms used for convenience, as nothing definite is known about which way electricity flows.

**174. Electrical Units.**—The difference in potential at any two points on a conductor is the pressure that makes the current flow from one point to the other. All conductors offer some resistance, and hence this pressure is necessary. This pressure is also called electromotive force (E. M. F.). The unit of electromotive force is the *volt*, named after *Volta*, an Italian scientist. Electric lamps in the house are usually lighted with a current of 110 volts. Electric street cars use from 500 to 600 volts.

The strength of current is measured by a unit called an *ampere*, named after a French physicist. A unit current is a current of one ampere.

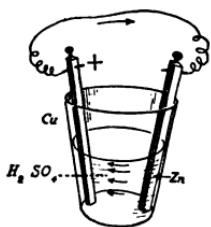
All conductors offer resistance to an electric current, and the unit for measuring this resistance is the *ohm*. We may now define *volt* as that potential difference or E. M. F. which will drive a current of one ampere through a resistance of one ohm. These units will be more clearly understood when we work with electric cells and machines. However, the relation that these three units bear to one another can be partially understood from the

following expressions by which any one of the three units can be found if the other two are given.

$$(1) \text{ Current} = \frac{\text{Electromotive Force}}{\text{Resistance}}, \text{ or } C = \frac{E}{R}$$

$$(2) \text{ Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

**175. The Simple Electric Cell.** — Place some water in a small glass beaker or tumbler and then add a few drops of sulphuric acid or hydrochloric acid. Place in it on opposite sides a clean strip of zinc and one of copper, as shown in the figure. This is the simple Voltaic cell and is capable of supplying a continuous flow of electricity through a wire which joins the strips of copper and zinc. It will be observed that the zinc strip wastes away when the current flows. The eating away of the zinc by the acid furnishes the energy necessary to drive the electric current through the liquid of the cell and the external wire connection.



A SIMPLE CELL

Made of copper and zinc strips standing in sulphuric acid.

The current may be thought of as a kind of chemical furnace in which fuel is consumed to drive the current. Since zinc will burn in a stove, it can be thought of as the fuel, the acid is the oxidizer, and the copper is a metallic hand in the cell, which gathers the current but takes no part in the chemical action. Before the zinc and copper are connected by a wire, the zinc is trying to dissolve in the acid and throw a current across to the copper, while the copper is also trying to dissolve, but with less force, and to throw a current across to the zinc.

The potential or electrical pressure of the zinc is about 1.86 volts higher than that of the liquid, while the copper has a potential of only 0.81 volts higher than the surrounding liquid, because the copper is oxidized less easily than the zinc. So the zinc has a potential of about 1.05 volts higher than the copper, but still there will be no flow of electricity that can be detected until the copper is connected to the zinc by a conductor. If the zinc and copper are made to touch at the top or are connected by a long conductor, there will be a rush of electricity through the acid from the zinc to the copper and from the copper to the zinc through the external conductor, as indicated by the arrows in the illustration. A small portion of the zinc is at the same time dissolved, the zinc parting with its stored energy as its atoms combine with the acid. This energy is spent in forcing electricity through the acid to the copper strip and thence through the external circuit back to the zinc strip.

Electricity flows from high potential to lower potential, or from positive to negative, represented by plus (+) and minus (-) respectively. Since the current flows from the zinc to the copper in the liquid, the zinc is the positive plate and the copper the negative plate when the current in the cell is under consideration. Since the current leaves the cell by way of the copper strip and flows through the wire to the zinc, the copper is the positive pole and the zinc is the negative pole, when the external circuit is under consideration.

If two copper wires are united to the tops of the two strips, one to the zinc and one to the copper, though no current flows as long as the two wires are kept separate, the wire attached to the copper will have a positive charge and the one attached to the zinc will have a

negative charge, because of the tendency of the zinc to oxidize and drive a current through the cell to the copper. This means that the electricity will flow to the end of the wire and then stop unless a connection is made for a complete circuit. The starting point of the current is not in the wire but at the zinc plate where chemical action furnishes the energy. As each atom of zinc unites with the acid molecules and liberates hydrogen an electric charge is produced, and the sum of all of these little charges keeps up the potential difference or electromotive force which drives the current through the entire circuit. The current is made up of the sum of the charges carried by the hydrogen atoms to the copper plate. These hydrogen atoms soon collect on the copper plate in such quantity that hydrogen bubbles are formed. As the hydrogen collects on the copper, making it a less negative plate, the current continues to decrease, because the potential difference or electromotive force is not sufficient to drive it. *The cell is said to be polarized when the copper plate is covered with hydrogen bubbles.* The polarization of a simple cell takes place so rapidly that the current decreases to almost nothing in a few minutes.

If hydrogen bubbles escape from the zinc when it is placed in the cell alone or when the external circuit is not closed, it means that local currents are set up on the zinc itself, due to the impurities in the zinc. The impurity in the zinc may be iron or some other metal which receives the electric charge from the hydrogen atoms and then the hydrogen is set free and the current flows from the impurity in the zinc to the pure zinc, making short circuits. *This local action can be prevented by dipping the entire strip of zinc in dilute sulphuric acid and*

*then spreading over it a thin coat of mercury. This process is called amalgamation.* The mercury unites with the zinc and forms a pasty amalgam. As the acid takes the zinc out of the amalgam, the mercury unites with other zinc beneath the surface and so keeps the same amount of amalgam on the surface. The iron does not dissolve in the mercury but floats to the surface of the amalgam, from which a few hydrogen atoms will remove it.

**176. How to Prevent Polarization.** — An electric cell which does not give a comparatively constant current, for a short time at least, is not of much value. There are three possible ways of preventing polarization, but only two of them are practical.

(1) If the hydrogen bubbles are brushed from the copper plate, or if the liquid of the cell is stirred sufficiently, the bubbles will be removed and escape to the surface. This is a purely *mechanical method* and very inconvenient. Various modifications of this method have been devised but without much success.

(2) *Chemical Means.* — If there is added to the liquid of the cell a substance which will oxidize the hydrogen as fast as it is liberated at the copper plate, the chemical action on the zinc remains constant and so the current does not decrease. Some oxidizing substances used are bichromate of potash, nitric acid, and manganese dioxide. The chemical means of preventing polarization is used very extensively. Manganese dioxide ( $MnO_2$ ) is the depolarizer in the common dry cell.

(3) *Electrochemical Means.* — In this method the copper plate is in a copper sulphate solution and so pure copper atoms are deposited on the copper plate instead of hydrogen. This prevents all polarization as the deposited

copper offers no more resistance to the current than does the original plate.

**177. The Daniell Cell.** — There are several types of the Daniell cell. The two common forms are shown in



DANIELL'S CELL

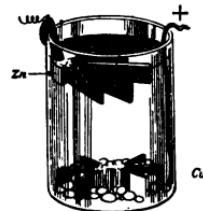


the illustrations. The negative pole is zinc, which is immersed in dilute sulphuric acid or zinc sulphate in an unglazed earthenware cup. The positive pole is copper, which is in a copper sulphate, The solution is kept the same strength by

the copper sulphate crystals dissolving as copper is taken out of the solution and deposited on the copper pole.

The chemical action which develops the current in this cell is as follows: The acid acts on the zinc pole and forms zinc sulphate ( $ZnSO_4$ ) and free hydrogen is liberated. The hydrogen atoms with their electrical charges pass through the porous cup and come in contact with the molecules of copper sulphate. The hydrogen displaces the copper of the copper sulphate and forms sulphuric acid ( $H_2SO_4$ ). The displaced copper atoms take the electrical charges from the hydrogen atoms and carry these charges to the copper pole, to which the copper atoms adhere when they give up their electrical charges. No polarization can occur since no gas is liberated at the positive pole. Such a cell has an electromotive force of about 1.1 volts.

**178. The Gravity Cell** is so called because the heavy solution of copper sulphate stays at the bottom and the



GRAVITY CELL

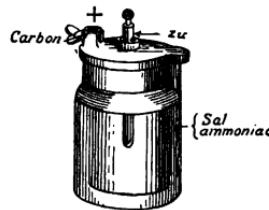
zinc sulphate remains on the top. The zinc plate dissolves in the zinc sulphate. The zinc of the zinc sulphate replaces the copper of the copper sulphate where the two solutions touch. The liberated copper atoms are thus given electrical charges which they carry to the copper plate at the bottom of the cell and they adhere to the plate when the charge is given up. The copper sulphate crystals in the bottom are dissolving to keep up the strength of the solution. Polarization cannot occur in this cell as no gas is liberated.

This type of cell is used extensively in telegraphy, where the circuit is kept closed nearly all the time.

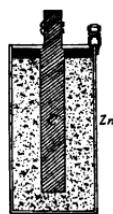
**179. The Dry Cell.** — The dry cell is a form of the Leclanché cell. It is made by taking a cylindrical zinc cup, which serves as the negative pole, and putting into the middle of the cup a carbon rod for the positive pole and then filling the intervening space with a spongy or paste-like substance containing zinc oxide, sal ammoniac,

zinc chloride, plaster of Paris, and water. Sometimes powdered manganese dioxide is mixed with the paste, and the top is sealed to prevent evaporation. If the cell is given continuous use, it polarizes in a short time and then needs rest or time for the hydrogen to be oxidized by the manganese dioxide, or to escape through a small hole left in the top.

The dry cell is portable and is used very widely where a continuous current is not needed. It is convenient for door bells and is used for producing the electric spark which ignites the gas in gas engines. The com-



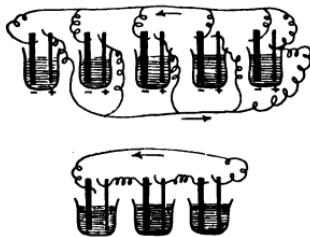
MODIFIED LECLANCHE  
CELL



DRY CELL

mon dry cell in good condition has an E. M. F. of about two volts.

A battery consists of a number of cells connected in series or in parallel. When cells are in parallel the positive poles are joined to positive poles and the negative poles to negative poles. When cells are in series they have the positive pole of one connected with the negative pole of the next and so on. The E. M. F. increases when cells are connected in series, and the current increases when they are connected in parallel.



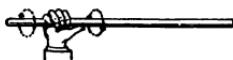
CONNECTED CELLS

The cells in the upper row are connected in parallel; those in the lower row, in series.

**180. Magnetic Field about a Current.** — From the chapter on magnets we found that a magnet has a magnetic field about it and that the lines of force come from the *N* pole and pass through the air to the *S* pole, and that a small compass, while held in the magnetic field, points in the direction in which the lines of force are going. To show this, connect two or more electric cells in parallel and have part of the wire of the external circuit in a vertical position and passing through a sheet of paper as shown in the illustration. Sift some very fine iron filings on the paper and jar the paper very gently to cause the filings to adjust themselves to the magnetic lines of force going around the wire. It will be found that the wire is in the center of all the circles formed. Now place one or more small compasses on the paper near the wire and determine which way the lines of force are traveling. The compass needle will point in the direction in which the lines of force go.

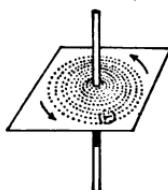
Now determine whether the current is going up or down through the wire, by examining how it is connected with the poles of the cells. If we change the connection to reverse the current we shall find that the compass needles will also change their direction. This means that the lines of force have changed the direction in which they are going around the wire. One way of finding which way the lines of force are going about a wire carrying a current is by the right-hand rule. *Grasp the wire in the right hand with the thumb pointing in the direction in which the current is going; the fingers then encircle the wire in the same direction as the magnetic lines of force.*

Now let the wire carrying the current be bent into a small coil of one turn and insert a small compass when the coil is held in a north-and-south position and observe the direction in which the needle points. If we reverse the direction of the current by changing the connections on the cells, the needle will also reverse its direction. In both conditions the needle points in the direction in which the magnetic lines of force are passing through the coil. If these lines of force are followed by moving the compass in the direction in which the needle points, we find that they come out of one side of the coil, go around the



THE RIGHT-HAND RULE

wire, and go into the other side of the coil. The side into which the magnetic lines of force go is called the south pole of the coil and the side from which they



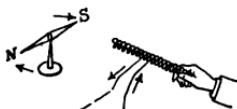
MAGNETIC LINES  
ABOUT A WIRE  
CARRYING A  
CURRENT



LINES OF FORCE  
Around a single coil.

come out is the north pole. This can be proved by holding the compass at either side and observing which pole of the needle is attracted.

Wind a wire around a pencil like the threads on a



CURRENT THROUGH  
THE HELIX

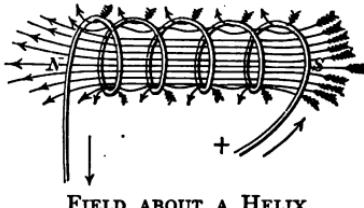
Affects the compass.

screw. Remove the pencil and connect the ends of the wire forming the coil, commonly called a helix, with a good electric cell. Hold one end of the helix near a suspended magnet or compass needle. (See illustration.) The helix will act in

every respect like a magnet, with an *N* pole at one end and an *S* pole at the other. By reversing the helix and pointing it at the *N* pole of a compass needle each time, we can easily find which is the *N* pole of the helix and which end is the *S* pole.

The magnetic lines of force go into the *S* pole end of the helix and come out of the *N* pole end. If the current goes around the helix in the right-hand-

screw direction, the magnetic lines of force go through the helix in the same direction that the current goes from one end to the other. By reversing the current the lines of force will also reverse.



FIELD ABOUT A HELIX



HELIX WITH CORE

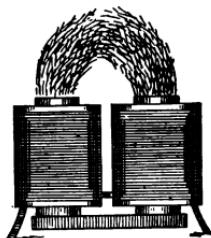
**181. The Electromagnet.** — The helix is a form of electromagnet. By inserting in the helix an iron rod which will serve to conduct the magnetic lines of force, the effect upon the compass needle is much more evident. The iron rod will also pick up iron filings. By doubling the number of turns

of the wire around the iron rod, its magnetic force will be doubled. By doubling the current the magnetic force will also be doubled. *The strength of an electromagnet is determined by the current or the number of amperes and the number of turns in the coil.*



HELIX OF MANY TURNS OF WIRE

Electromagnets are usually made in horseshoe form, with a soft iron core extending through each coil. The iron cores are connected by an

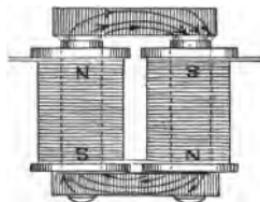


HORSESHOE ELECTROMAGNET.

iron bar called an armature. The cores and armature make a metallic circuit for the lines of magnetic force and prevent them from passing through the air, thus preserving the entire force of the magnet. The iron object lifted serves as a second armature. The coils are wound in such a way that the

current passes around them in opposite directions, and therefore the poles of each coil are reversed. A soft iron core is used because the soft iron is a magnet while a current is passing through the coil, and it loses its magnetism as soon as the current is broken.

Electromagnets are used for loading and unloading iron. A large magnet is fastened to a hoisting crane and lowered to a pile of iron. The current is turned through the coils of the magnet and the iron adheres to it. The crane lifts the magnet with the iron adhering to it and swings it to the desired place; the current is then cut off



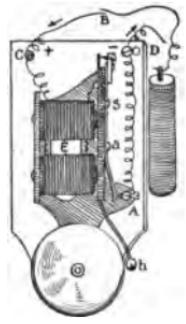
SHOWING POLES, LINES OF FORCE, AND DIRECTION OF CURRENT

and the load of iron drops at once. Electromagnets are also used in electric bells, in telegraph and telephone instruments, and in electric power generators.

**182. The Common Electric Bell.**—The dry cell is usually used for the operation of an electric bell, since a continuous current is not necessary.

In the illustration, when the push button, *B*, is pressed the electric circuit is closed, and a current flows from the battery to *C*, thence through the coils of the electromagnet, over the closed contact *A*, and out again at *D*. No sooner is this current established than the electromagnet *E* pulls over the armature *a*, and in so doing breaks the contact at *A*. This stops the current, and the magnet *E* at once loses its magnetism. The armature is then drawn back against *A* by the spring *S*. As soon as the contact is made at *A* the current again begins to flow and the previous operation is repeated. The circuit is thus automatically made and broken at *A*, and the hammer *h* is made to vibrate very rapidly, striking the bell at each vibration, thus producing the ringing noise.

ELECTRIC BELL



The diagram illustrates the internal mechanism of an electric bell. It shows a battery with terminals labeled '+' and '-' connected to a push button labeled 'B'. The circuit then splits into two parallel paths. One path goes through a contact labeled 'A' and then to a terminal labeled 'D'. The other path goes through a coil labeled 'E' (the electromagnet). Both paths converge back to the same terminal 'D'. A small spring labeled 'S' is shown near the contact 'A'. Below the coil 'E' is an armature labeled 'a' attached to a hammer labeled 'h'. The hammer is shown in two positions: one where it is pulled back by the magnet and another where it has struck a bell. The entire assembly is labeled 'ELECTRIC BELL'.

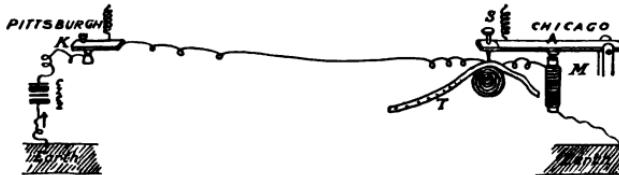


PUSH BUTTON FOR  
ELECTRIC BELL

**183. The Telegraph.**—The electric telegraph and the telegraphic code or alphabet were invented by S. F. B. Morse in 1832. The first public exhibition of the instrument was made in 1837 in New York City, when a message was sent over a copper wire 1700 feet long. The first commercial telegraph line was built in 1844, between Baltimore and Washington, by the aid of a \$30,000 grant from Congress. On May 24, 1844, the inventor

sent the famous message, "What hath God wrought." This was the first message sent over the wire from Washington to Baltimore. From that time telegraph systems increased rapidly, until now a message can be sent around the world in a few minutes.

When the key, *K* (see illustration), in Pittsburgh is closed the current flows over the line to Chicago. There it passes through the electromagnet, *M*, and thence back to Pittsburgh through the ground. The armature, *A*,



SHOWING THE PRINCIPLE OF THE TELEGRAPH

is held down by the magnet, *M*, as long as the key, *K*, is kept closed. As soon as the current is broken by releasing the key, *K*, the magnet, *M*, is demagnetized and the armature, *A*, is pulled up by the spring, *S*. By means of clockwork the tape, *T*, is drawn along at a uniform rate beneath the pencil or pen held by the armature, *A*. A very short time of closing of the key, *K*, produces a dot upon the tape; if the key is closed for a longer time a dash will be produced. By this simple method a message could be sent to Chicago without the operator at Chicago being present at the time.

Many improvements have been made on the Morse system so that now operators can call one another and can take a message by sound, thus avoiding the necessity of having the writing apparatus. A very short interval of time between two clicks of the sounder is interpreted as a dot, a longer interval is interpreted as a dash.

**184. Relay and Sounder.** — On account of the great resistance in the external circuit of long telegraph lines,

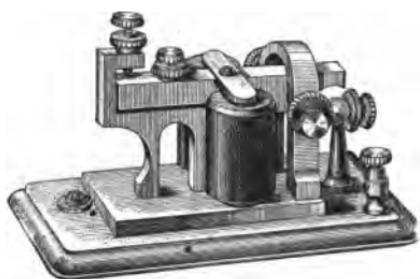
it is not possible to drive a current of sufficient strength through them to operate the electromagnet of the sounder so that the armature is drawn against

the post hard enough to make a sound that can be heard distinctly. Therefore an instrument is used which is very similar to the sounder. It is called the relay.

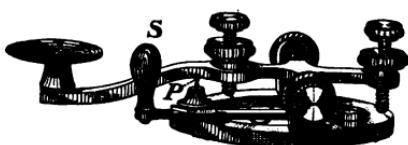
The coil of the electromagnet of the relay is made of many thousand turns of very fine wire, and the movable armature is very light in order that the feeble

current going through the coil of the magnet can move it.

Since the clicks of this light armature on the relay cannot be heard, there is at each station a local circuit



RELAY

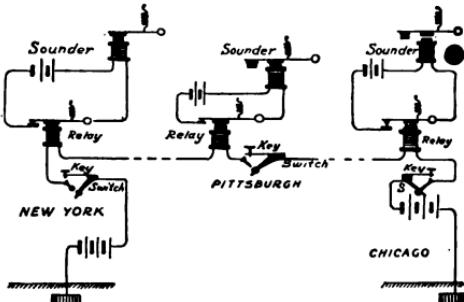


SENDING KEY

with a local battery, and another instrument called the sounder, which has a heavy armature that can be distinctly heard when moved by a strong electromagnet connected with the local battery. The armature

on the relay makes and breaks the local circuit so that the sounder repeats the movements of the relay, but with

increased force because of the local battery which operates the sounder. The armature of the sounder clicks when it is drawn down by the magnet, and also when it is drawn back up by a strong spring. The time elapsing between two successive clicks indicates to the operator whether it is a dot or a dash.



A TELEGRAPH SYSTEM

The circuit of a telegraph system is kept closed when not in use. When the operator in Pittsburgh wishes to send a message to Chicago, he opens the switch and



AMATEUR WIRELESS RECEIVING AND SENDING APPARATUS

operates the key which makes and breaks the circuit as the dots and dashes are made. The sounder in Chicago

being in closed circuit responds to the operator in Pittsburgh. The operator in Pittsburgh opens his switch and calls the operator in Chicago and then closes his switch and waits for a response. The operator in Chicago opens his switch and responds to the Pittsburgh call and then closes his circuit again. The Pittsburgh operator now opens his switch and proceeds to send his message, which the operator in Chicago writes as he hears the dots and dashes.

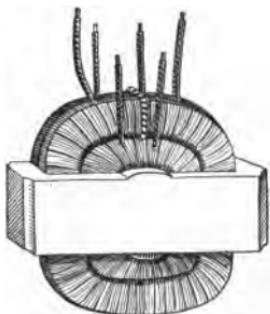
**185. Electric Lights.** — Most electric lights in houses are made to take a current with an E. M. F. of 110 volts. The filament in the lamp resists the flow of the current to such an extent that it is made white-hot as a result, and thus radiates light and some heat. A lamp with a tungsten filament takes about only one-third as much current as a lamp with a carbon filament, both making the same amount of light.

Since the E. M. F. of the current delivered by a 60-cycle alternating generator is 2200 volts, it is necessary

to have some way of reducing this voltage so that the lamps can use it and so it will be safe to run it into the houses. A very simple apparatus, called a transformer, is used for the reduction of voltage.

The transformer consists of a laminated iron ring with two coils wrapped on it. These two coils are not connected, and when a current passes through one coil an induced current passes through the other coil.

A transformer will work only when there is an alternating current, because it does not rotate through a mag-



A TRANSFORMER

netic field. When the lines of force set up by the primary coil pass around the transformer and into the secondary coil, a current is induced which flows in the opposite direction from that in the primary coil. When the current in the primary coil changes its direction, the lines of force pass around the transformer in the opposite direction from that at first and into the secondary coil,



ELECTRIC POWER PLANT

and so a current is set up opposite to the first current in the secondary coil.

The voltages of the primary and secondary coils have the same ratio as the number of turns of wire in the primary and secondary coils. If the voltage in the primary is 2200 and the number of turns of the primary on the transformer is 4400, the voltage in the secondary will be 110 if the turns of the secondary on the transformer are 220. Transformers are usually enclosed in metal cases which can be seen on poles carrying electric light wires.

**186. The Telephone.**—The telephone was invented by Alexander Graham Bell, of Washington, in 1875.



(C) Underwood and Underwood

**ALEXANDER GRAHAM BELL**

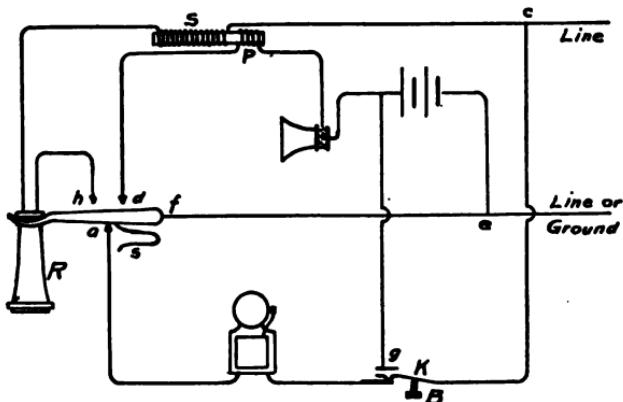
Scientist and inventor, born March 3, 1847, educated in Edinburgh and London, invented the telephone 1875. He also invented the photophone, induction balance, telephone probe for painless detection of bullets in the human body, and assisted in the invention of the graphophone.

It has been in extensive commercial use only about 25 years. It was at first a luxury, but has become a necessity in modern business. Telephone lines are found along nearly every public highway. The telephone, however, does not transmit sound. The sound waves that are made when one speaks into the mouthpiece of a telephone control the electric current which passes over the telephone wire and into the receiver at the other end. The

current going into the receiver causes an elastic piece of sheet steel to vibrate with the same speed and quality as the voice of the speaker which made the elastic sheet steel in the mouthpiece vibrate. When the sheet steel in the receiver vibrates it causes the air between it and the ear-drum to vibrate and thus the sound is carried to the ear.

The modern telephone uses an induced current that passes over the wire, rather than the current direct from the battery. Hence a transformer, a form of induction coil, is necessary to make the induced current. The coil on the transformer connected with the battery is

called the primary, and the coil on the transformer connected with the telephone line is called the secondary. The current from the battery goes to the back of the diaphragm in the mouthpiece, from which the current passes through a little chamber which is filled with fine granular carbon, to the conductor of the trans-



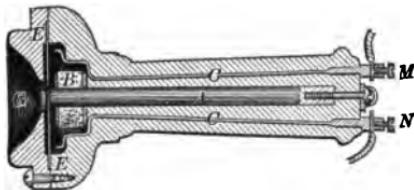
SIMPLE TELEPHONE SYSTEM

mitter, and thence through the primary, *P*, of the induction coil and then back to the battery.

As the diaphragm vibrates it varies the pressure on the many contact points of the granular carbon through which the current flows; this causes considerable variation in the resistance of the local circuit. When the diaphragm moves toward the fine carbon a large current flows through it to the coil, *P*. When the diaphragm moves back from the carbon a much smaller current flows. These changes of flow in the primary coil produce a change in the magnetism of the soft iron core of the induction coil, and there is a like change in the induced or secondary current coming from the secondary coil and passing over the line to the receiver at the other end.

This induced current going into the receiver causes the diaphragm in it to vibrate the same as did the diaphragm in the transmitter.

The receiver, as shown in the illustration has a permanent long U-shaped magnet with electromagnetic coils on each end of the magnet.

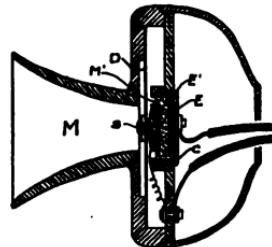


TELEPHONE RECEIVER

*E*, the vibrating diaphragm and *BB* the electromagnets.

The coils are made of a large number of turns of fine wire and each has a soft iron core, the end of which is very near the diaphragm.

When the current goes around these coils in one direction the permanent magnet is strengthened and the diaphragm is drawn back to the magnet. When the induced current is reversed and goes through the coils in the reverse direction the magnetism of the permanent magnet is overcome and the diaphragm moves out from the poles of the magnet. These changes in the strength of the magnet are made as fast as the diaphragm of the transmitter vibrates, and so the diaphragm of the receiver vibrates exactly the same as that of the transmitter; thus the same kind of sound waves is transmitted to the air as were made by the voice of the speaker. The extension of the mouthpiece is simply to reflect the sound waves to the diaphragm. The object in the mouthpiece full of holes is to protect the diaphragm.



TELEPHONE TRANSMITTER

QUESTIONS AND EXERCISES

1. Comb your hair rapidly with a hard rubber comb and then apply the comb to some small pieces of paper or pith balls. Explain what happens.
2. Rub a glass rod with a woolen cloth or cat's fur and apply the glass rod to some small pieces of paper. Observe results.
3. Compare these results with the results produced by magnets.
4. Why are lightning rods put on tall chimneys?
5. Where is the best place to be during a thunder storm? Why?
6. What causes electricity to flow over a wire?
7. How many volts and amperes are used by your electric lamps at home? ( $\text{Volts} \times \text{amperes} = \text{watts}$ .)
8. Examine a dry electric cell. Will it give a continuous electric current very long? Why? Which pole is negative?
9. What practical use is made of dry and wet electrical cells?
10. How can you make an electromagnet? What practical uses are made of electromagnets?
11. Examine your electric bell and push button. Explain how it works.
12. Does a telephone carry sound? Explain.

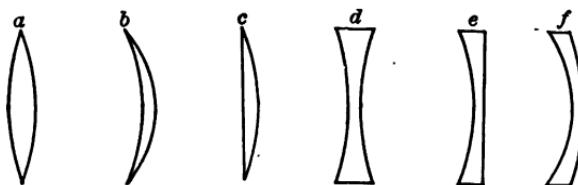
## CHAPTER XXVII

### LIGHT

**187. Diffused Light.** — From our observations and experiences with light and shadow we know that light travels in straight lines, except when it is reflected by an object or refracted by passing into or out of a transparent substance at an oblique angle. When light falls on rough surfaces like those of trees, fences, roads, etc., it is reflected in all directions. If light falls on smooth water or on a mirror it is not diffused, but all the light is reflected in such a way that we see an image of the object from which the light is coming.

Our living rooms would be very imperfectly lighted if it were not for the reflection of diffused light through the windows by the objects outside and if the walls of the rooms did not reflect the light. Reflection of light prevents the shade of trees and houses from being very dark. On cloudy days the light of the sun is reflected from one drop of water to another in the cloud until it finds its way to the earth. The thicker the cloud the less light can get through, and at times the clouds are so dense that artificial lights have to be used to enable us to see. The air is full of very small dust particles. The light reflected back and forth from these particles of dust helps to give the sky a blue color on clear days. Fine water particles like mist give the sky a grayish color.

**188. Lenses.** — Converging lenses are thick in the center and thin at the edge. The light which passes through them is refracted or bent from its straight path



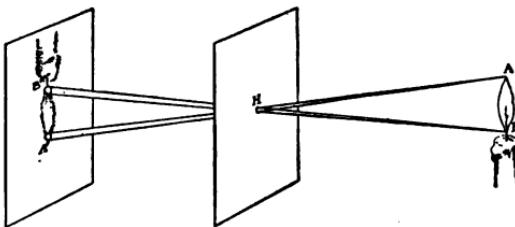
LENSES

*a, b, and c, are Converging, and d, e, and f, Diverging Lenses.*

so that it will pass through a point. These lenses are used in simple magnifying glasses, microscopes, telescopes, cameras, and in eye-glasses for farsighted people.

Diverging lenses are thin in the center and thick at the edge. The light which passes through them is made to diverge or spread apart. They are used in eye-glasses for people who are nearsighted, and sometimes they are used in the small end of opera glasses.

**189. Cameras.** — With a pin or pencil make a small hole in a sheet of paper and hold it before a light or toward a window; place back of the hole another sheet of paper, and on it you will see a picture or image of the object from which the light is coming. This is known as a "pin hole" camera. A picture can be taken with it if a light-tight box is



FORMATION OF A PINHOLE IMAGE

made and a sensitive plate is exposed in it back of the pin hole, which acts as a lens.

A camera is a box, black inside, and made so that light can enter only through a converging lens. The lens, when focused, throws an image on a plate or film which is covered with a chemical that is sensitive to light; each part of the plate is affected according to the amount of light striking it. The light parts of an object which is being photographed throw more light into the camera than the darker parts, and these light parts of the object will affect the sensitive plate more than the darker parts. The exposed plate is developed by washing it in the proper chemicals, and it is then known as the "negative," because its shades are opposite to those of the object photographed. Positive prints are made by allowing light to pass through the negative to sensitive paper, which is then developed by washing it in the proper chemicals.

**190. The Spectrum.** — When a beam of ordinary white light passes through a prism it is not only refracted but is



SPECTRUM FORMED BY A GLASS PRISM

also *dispersed*, i.e. it is separated into what appears to the eye as a series of different hues or colors, called a *spectrum*. The order of the colors in such a spec-

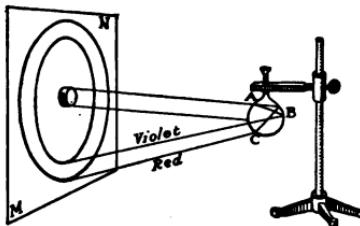
trum is red, orange, yellow, green, blue, and violet, the red having the least, and the violet the greatest, angle of deviation, as shown in the diagram.

**191. Rainbow.** — A very beautiful natural spectrum, with which everyone is familiar, is the rainbow. The rainbow is usually seen just after a rain during the latter

part of the day, when the bright sun appears before the cloud has disappeared. The reason that a rainbow is not seen in the morning is because the clouds as a rule travel from west to east, and the front of the cloud usually hides the sun before any rain falls. After the cloud is past, the sun is not in the right position to shine on the falling drops. So rainbows are seen by looking east just after a shower, and usually in summer, because the winter clouds do not pass away quickly enough for the sun to shine on the falling rain.

To understand how a rainbow is made, let us examine the illustration. *MN* is a large cardboard with an opening at *O* for the light of the sun to enter the room. The light passes into the two-inch spherical flask at *A*, and is refracted as it enters, just as when light passes through a prism. It goes through the water to the other side of the flask at *B*, from which it is reflected to *C*. As it comes out of the flask at *C* it is refracted again, thus spreading the red and violet rays farther apart. From *C* the light goes to the cardboard, with the violet and red at the positions indicated and the other colors of the spectrum between the red and violet. Since violet is refracted most, it will be nearest the center of the circle. Only one ray of light is represented in the drawing, but the rainbow spectrum is a complete circle around the hole *O*.

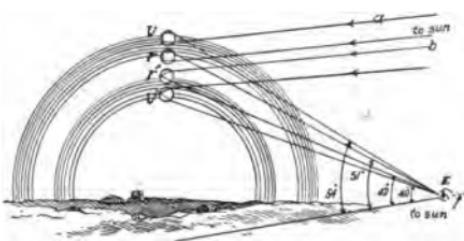
The natural rainbow seen after a rain is due to the refraction of the sunlight as it passes into and out of a drop of falling water and the reflection of this light from



PRODUCING AN ARTIFICIAL RAINBOW

the opposite surface of the drop so that it comes out of the drop in the direction toward us. The falling drops act on the light just as the flask in the illustration did.

The illustration on this page represents a natural rainbow with a secondary one above it. The secondary bow is usually seen only in part. Since the rainbow is in a comparatively fixed position at any one time, and since a drop of falling water must be in a certain position



SHOWING HOW PRIMARY AND SECONDARY RAINBOWS ARE FORMED

with respect to us in order to refract and reflect the light to us, the time during which one drop helps to make the rainbow is a very small fraction of a second. So the falling drops must

be quite numerous in order to make a continuous colored arch. Since violet is refracted more than red, the violet appears on the inside of the circle and the red at the outer edge, with the other colors between. As the drop descends through the position where it will throw the colors to our eye, the ray of light, *a*, passes into the lower part of the drop, is reflected twice from the opposite surface, and then refracted again as it comes out. As violet is refracted most, the drop will throw violet color to our eyes first from position *v*, followed by the other colors of the spectrum, ending with red in position *r*. From *r* the drop passes down into a space from which it cannot throw any colors to our eyes until it descends to position *r'*. Here the ray of light *b*, passing into the upper part of the drop, is refracted, then reflected from the opposite side,

and refracted again as it leaves the drop. Since red is not refracted so much as violet, the drop throws first to our eyes red and then the other colors of the spectrum, ending with violet from the position  $v'$ . As the drop falls from  $v'$ , it does not cast any color into the eye at  $E$ .

The distance of the falling drops from the eye is what determines the height of the rainbow. The reason that the rainbow is an arc of a circle is because every drop that throws the colors to the eye must be in a certain position with respect to the eye. If a line is drawn from the eye to the center of the circle of which the rainbow is a part, all of the drops of water, while passing through the rainbow are equally distant from the eye and any point on the line. This line drawn from the eye to the center of the circle of which the rainbow is an arc forms an angle of  $40^\circ$  with the line drawn from the eye to the violet color of the rainbow, and an angle of  $42^\circ$  with the line drawn from the eye to the red part of the rainbow. If a person were on top of a very high building it would be possible to see almost the complete circle of the rainbow. While standing on the ground, where it is level or nearly so, not quite one-half of the circle can be seen.

No two persons can see exactly the same rainbow, because the eyes must be at a given angle from the drops that make the colors. When a person moves, the rainbow moves also. If we move toward the rainbow, it may keep at about the same distance from us as when we started, depending upon how fast the cloud is moving.

A rainbow spectrum can be made with a street sprinkler, hose, or sprayer in the morning or afternoon when the sun is shining. Glass prisms on lamps, angles in glass

doors, cracked glass, and waves of water will produce refraction of light so that the rainbow colors can be seen.

#### **QUESTIONS AND EXERCISES**

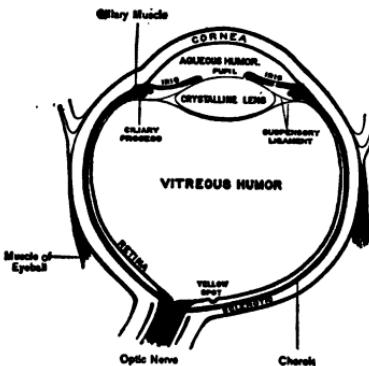
- 1.** What kind of objects can be seen? Which kind cannot be seen?
- 2.** To have properly lighted rooms, what color of paper should be on the walls? Why?
- 3.** What practical uses are made of lenses?
- 4.** Bring your camera to school and learn the use of its parts so you can take better pictures.
- 5.** What time of the day are most rainbows seen? Why? What is the arrangement of the colors of a rainbow?
- 6.** How can rainbow colors be produced on a clear day?

## CHAPTER XXVIII

### THE HUMAN EYE

**192. Structure of the Eye.**—The complete eye consists of three parts, namely, the eyebrows, which prevent perspiration and dust from touching the eyeball; the eyelids, which protect the eyeball and keep out dust; and the eyeball itself. The normal eyeball is nearly spherical and the outer part is composed of three layers; the inner part is filled with three transparent substances, two of which are almost like thin jelly in texture.

The illustration shows the parts of the eye. The front part is a very tough substance called the *cornea*. The cornea has the power of refracting light and acts as a converging lens. Just back of the cornea is a watery liquid called *aqueous humor*. It is transparent and helps to hold the cornea in position. Back of this aqueous humor is a thin muscle called the *iris*. The iris is the middle layer of the outer part, and it goes all around the eyeball. The color of the iris in front gives the various colors to the eyes, such as gray, blue, or brown. The iris has a round hole in it which is called the *pupil* of the eye. The iris, a muscle, changes



SECTION THROUGH THE EYE  
Showing the parts.

the size of the pupil to regulate the amount of light entering the eye.

While we are in the sunlight or in a room where the lights are bright, the pupil is small, but when we are in the dark the pupil is very large. The changing of the size of the pupils of your eyes can be seen by going suddenly from a dark room into a lighted room and watching for the change by looking into a mirror; or by closing the eyes for a moment in a lighted room and then opening them suddenly and looking into a mirror. When we go from the bright sunlight into a house, especially if snow is on the ground, we cannot see distinctly for a while, because the iris does not adjust itself quickly after being in strong light for some time.

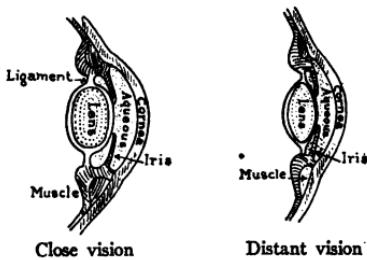
Just back of the iris is the colorless *crystalline lens*, which is double convex and refracts the light and forms an image just as does the lens in a magnifying glass. The crystalline lens is held in position by a ligament which goes entirely around it, much like the frame of a magnifying glass which holds the lens. The crystalline lens can change its shape and can become thicker or thinner through the center. When the ligament around the lens is loosened by the action of a muscle, the thickness of the lens is increased. When this circular muscle relaxes, then the ligament in which the lens is held pulls outward and makes the lens thin but broader. When we read, the lens is made thick; when we observe distant objects the lens is made thin or less convex, so that the image formed by it falls on the right place.

Back of the crystalline lens is the largest part of the eye, which is filled with a transparent substance called *vitreous humor*. This helps to keep the eyeball in shape and acts somewhat as a lens. The *retina* lines the entire

cavity containing the vitreous humor. It contains the nerves of sight and is connected with the large optic nerve.

The eye is a much more perfect optical instrument than the camera. The lens of the camera must be moved back and forth until a distinct image is formed on the screen. The lens must also be changed for various distances. The eye adjusts itself almost instantly to form images of near and far objects. The image formed by a normal eye is much more distinct and accurate than the image formed by the lens of a camera. The crystalline lens, instead of moving back and forth to accommodate itself to various distances, simply changes its shape. For near objects it thickens, thus increasing the curvature and making the lens more convex, so that it can focus the rays of light on the retina. For distant objects the crystalline lens is made thin and less convex, so that the rays of light are not focused before they get back to the retina. *This process of adjustment of the crystalline lens is called accommodation.*

**193. How We See Objects.**—Nearly all objects reflect light, and this reflected light passes through the cornea and is slightly refracted. The cornea acts as a converging lens. The light then passes by way of the pupil through the crystalline lens, which is double convex and continues the refraction started by the cornea. An image of the object is formed on the retina. The retina contains nerves and is sensitive to this light forming the



SECTION OF THE FRONT OF THE EYE  
Showing the change of the lens for close and distant vision.

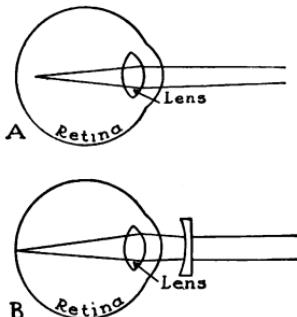
image. The disturbance in the nerve caused by the image is carried by the optic nerve to the brain, where it is interpreted, and then we become conscious of the presence of an object in our field of vision. We see objects because they reflect light into the eyes or because the objects are self-luminous. Our eyes, of course, reflect light so that another person can see them, but that part of the eye just in front of the pupil does not reflect any light, therefore the pupils of every person's eyes are black, and we can only distinguish the pupil of the eye by means of contrast. The iris, a muscle which regulates the size of the pupil, having the color blue, gray, or brown, reflects light as does the white part of the eyeball.

The nerves of the retina are able to receive about ten image impressions per second; that is, if ten objects were shown to us in a second, we could see each one distinctly. If less than ten are shown, we of course see them separately and each one makes a distinct impression. If more than ten objects are shown to us in a second, we cannot distinguish one from the other and they appear as a continuation of one object. If a stick with a spark of fire on the end is whirled rapidly, we see a streak of fire and not a spark in distinct successive positions. This is because the stick gets around the circle and makes a second impression or image on the retina before the impression of the first image is gone. The separate spokes in a rotating wheel cannot be seen for the same reason. The wheel of a rapidly moving automobile seems to be solid and not made of spokes. Moving pictures are operated on the same principle. A reel contains about 1,000 separate pictures an inch square. These are made to pass the lens in the projection lantern at the rate of fifteen or sixteen per second. Each picture shows the

actors in a very slightly different position and so the observer gets the impression that the actors are actually moving in the picture. Sometimes thirty pictures are thrown on the screen per second; this gives a better effect than sixteen per second.

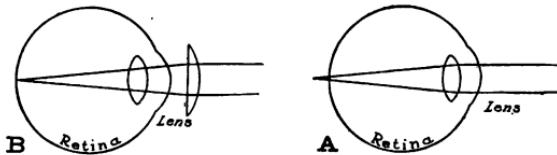
**194. Defects of the Eye.**—There are two common defects of the eye caused by the eyeball not having the proper shape and by the inability of the crystalline lens to adjust itself to various distances. Such eyes lack normal accommodation. The remedy is to wear glasses with lenses of the proper shape to make up for the defect of the eye.

(a) *Nearsightedness.*—This is most often due to the eye being too long from front to back. The rays of light are brought to a focus before reaching the retina which makes the object appear blurred or else it is not visible at all. Sometimes nearsightedness is the result of the cornea or the crystalline lens being too convex. This is usually caused by a weakening of the eyeball and does



NEARSIGHTED EYES

Showing the defect in *A* and the correction with a concave lens in *B*.



FARSIGHTED EYES

Showing the defect in *A* and the correction with a convex lens in *B*. not occur often in very young children. The remedy for nearsightedness is to wear glasses with diverging lenses.

(b) *Farsightedness* is caused by the eyeball being too short from the front to the back or by the crystalline lens not being sufficiently convex to bring the light to a focus on the retina. The light is not focused soon enough to see objects that are near. The person thus affected can often see distant objects better than a person with a normal eye, and usually holds a paper at arm's length when he reads. Farsightedness is a very common defect among people after they pass the age of fifty years. With young people it is rare. The remedy is to wear glasses with converging lenses.

(c) *Color Blindness*.—Men as a rule are not as much interested in the various shades of color as are women, and so they are not able to distinguish colors so readily, that is, to call them by name. This does not mean that men are unable to distinguish a difference between two shades of color, but that they may be unable to name the difference or even to name the colors under consideration. This is due to a lack of knowledge on the part of men and not to a defect of the eye.

Color blindness is a defect of the eye which makes it unable to distinguish any difference between certain colors. Red and green with their various shades are the colors which color-blind persons are unable to recognize. Their eyes do not respond to the ether waves that produce the sensation of red and green in the normal eye. The cause of the defect is not known and so cannot be remedied. Some investigators say that one out of every twenty male persons is color blind, while only one out of every two hundred females has the same defect. Red and green lights are the danger and safety signals used by the railroads and navigation companies, therefore it is very important for engineers and pilots not to be color blind,

Transportation companies do not put men who are color blind in positions where safety is dependent upon recognizing red and green lights.

(d) *Astigmatism and Headache.*—Astigmatism is a defect due to improper curvature of the cornea or crystalline lens so that the light is not properly focused, and imperfect images on the retina result. The muscles of the eye are continually trying to adjust the parts of the eye to form clear images. These overworked muscles soon become painful. The pain is felt in and around the eyeball and often in the front part of the head, where it is known as headache. Headache and smarting of the eyes after continued use, if the light is properly adjusted and the work not more than the normal eye can stand, are signs of astigmatism.

Headache and pain in the eyes are often caused by improper use of the eyes, such as reading or sewing in glaring or dim lights or by overwork in a place properly lighted. Reading ordinary print on a moving train or electric car soon produces pain in the eyes for most people, because of the continuous use of the muscles in keeping the parts adjusted and the eye directed to a definite spot on the shaking paper.

The remedy for astigmatism is to wear glasses of the proper kind, prepared under the direction of a well-trained oculist. The pain in the eyes and headache caused by astigmatism will be relieved if the proper shaped lenses are secured. Sometimes astigmatism may be permanently cured if the eyes are properly treated and cared for.

**195. Care of the Eyes.**—Numerous investigations have shown that most children are born with good eyes, and that the eyes become injured through improper use.

Children after starting to school often weaken their eyes by studying where the lights are too dim or too bright, or by sitting so that the light can shine into the eyes, or by reading books containing too fine print.

A book or paper should be held from ten to fifteen inches from the eyes for average sized print. While reading, the head should be held almost erect and the light so placed that it does not shine into the eyes; if possible the light should come over the left shoulder. Trying to read in dim light and leaning the head forward while reading cause pressure on the eyeballs, and nearsightedness may result. The eyes need rest the same as any other part of the body. If the eyes pain after long-continued work, the muscles controlling their adjustment need rest. Do most reading, writing, and sewing in daylight, especially if your eyes are slightly weak. Use shades on lamps, because most lamps throw most of their light upward and cast a shadow at their base. This shadow often falls on the book being read if a shade is not used to reflect the light downward. If properly used, the shade will also keep the light from shining directly into the eyes. Inflamed or weak eyes are often aided by bathing with a cupful of lukewarm water in which a teaspoonful of boracic acid has been dissolved.

**196. Light and Health.**—Sunlight is essential to the growth of trees, vegetables, and the cereal grains. These plants have a pale green, sickly look when for several days they do not get the proper amount of light. The heat and light of the sun furnish directly the energy for the growth of plants upon which man is dependent for food, clothing, and shelter. Artificial light is not sufficient for the growth of vegetation.

Man, like plants, without sunlight turns pale, has a

sickly appearance, and his blood loses much of its ability to destroy the tiny one-celled organisms which exist there in countless numbers. By working in the open air and sunshine the body is kept in good physical condition and is then able to resist the attacks of most foreign one-celled organisms. Bacteria, one-celled organisms, live mostly in dark, damp places and are not accustomed to much light. When they are exposed to sunlight, they die. For this reason living-rooms should be well lighted and as much of the direct sunlight should be permitted to enter the rooms as possible. The injury to the paper on the walls and to the carpet is not so expensive as ill-health. Faded paper does not produce the discomfort that lost health does. Paper and carpets that do not fade perceptibly in the presence of sunlight should be selected.

Hospitals are now built so that most of the rooms receive the direct rays of the sun during part of the day. Patients are often required to sit in the sun and open air. The sleeping quarters of tuberculosis sanatoriums are built with three open sides so that abundant light and air can enter. The recreation sheds are built with the south side entirely open so that the sun can shine into them. Sunlight and fresh air are the two great preventives of disease, and they will help to cure many diseases.

Artificial lights unfortunately do not kill many germs. Public buildings and offices where artificial lights must be used all the time are not the most healthful places in which to work. Such rooms and offices should be frequently disinfected. Many modern church buildings have such dark colors in the "memorial and picturesque" windows that scarcely a ray of sunlight can ever enter

to remove some of the dungeon-like gloom and throw a ray of hope into the hearts of the occupants, as well as to remove some of the disease germs that may be lurking there waiting for a victim. Modern factory builders have come to recognize the valuable effects of light on the workmen, and such buildings are filled with numerous large windows. The buildings of the National Cash Register Company of Dayton, Ohio, have so many large windows that they look almost like glass structures.

#### QUESTIONS AND EXERCISES

1. Name the parts of the eye. Give the use of each part.
2. Can you see objects that are black? Explain.
3. Explain why the persons in a moving picture show seem to be moving.
4. What are some defects of the eye? What is the remedy for such defects?
5. How can improper use of the eyes produce headache? Give the remedy for such a headache.
6. Make some general statements for the care of the eyes.
7. What is the relation between light and health?

## CHAPTER XXIX

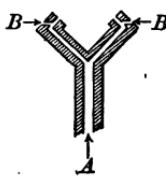
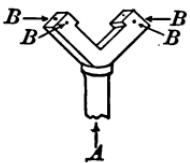
### ARTIFICIAL LIGHT

**197. The First Artificial Light.**— Primitive man did not have much use for artificial light because he did no reading or sewing; he found ample time during daylight to do his work. The open fire was the first artificial light employed by man. With fire some of the food was prepared and the rude dwelling places were lighted. Man then learned to carry a burning piece of wood while going about in dark caves or at night. Pine wood or wood dipped in animal oil or fat served well for this purpose. By experimenting with animal oil man found that it could be molded into sticks with some kind of a substance in the center to serve as a wick. As with all inventions it took many years for the candle to be perfected. The candle was used for several thousand years without much improvement or modification except in the method by which it was made.

**198. Oil and Gas.**— During this long period of man's improvement of artificial lighting from the discovery of fire to the perfected candle, and during many millions of years before this, there were being formed in the earth large quantities of petroleum, gas, and coal. These were formed of plant and animal matter which was deeply buried millions of years ago by the deposit of sand and clay which was carried by flowing water from the highlands into the low and swampy places and by the rising and sinking of the crust of the earth. It was not until recent

times that man discovered petroleum, coal, and gas, and learned how to get them out of the earth and use them. During the latter half of the nineteenth century and the beginning of the twentieth century, methods of artificial lighting have progressed by leaps and bounds. The candle was rapidly replaced with the oil lamp, which was at first very imperfect and dangerous because the gasoline could not be removed from the oil and hence lamps would occasionally explode. Improvements were made in the lamp and in the refining of the petroleum until it made an almost ideal light.

The discovery of natural gas led to the invention of a gas lamp which was used extensively in regions where



ACETYLENE BURNER AND FLAME

Air enters the openings at *B*.

gas was found. Gas lights were more convenient and less expensive than oil lamps. After the discovery of how to make gas out of coal, the gas lamp came into common use wherever coal could be secured at reasonable rates. The natural and coal gases were also used for cooking and heating after gas stoves were invented. Acetylene gas, a compound of carbon and hydrogen, is burned in the same kind of lamp as other gases. Vaporized gasoline is also much used for lighting, being burned in gas lamps.

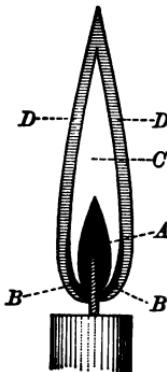
After the invention of machinery that would generate an electric current, electric lights soon came into use. With the improvements that have been made on the first

electric light, it has become the most convenient and effective method of lighting.

**199. How Lamps Make Light.**—Before animal oils or carbon oils can burn in a flame, they must be vaporized, that is, changed into a gas. The flame on the wick of a tallow candle melts the tallow. The liquid tallow is drawn up the wick and evaporated. The flame raises this vapor to the kindling point, at which temperature the carbon and hydrogen unite with the oxygen. The small carbon particles, as they unite with the oxygen, become so hot that they are self-luminous. These glowing particles of carbon in the flame of the candle are the light-producing part of the flame. If the flame is cooled slightly by blowing at it, a black smoke will come from it. This smoke is composed of unburned carbon.

The light of a carbon oil lamp is made by the glowing white carbon particles during their oxidation. The carbon oil is vaporized as it gets to the top of the wick. If the burner of a lamp is not clean, not enough air can pass through the holes below the flame and the vaporized oil cannot get sufficient oxygen for complete oxidation; the result is that the lamp smokes and poisonous gases come from it. If the wick is turned too high, not enough oxygen can enter the burner to oxidize the gas and smoking also results. A good oil lamp, well cared for, will not produce any smoke or bad odor, but will make a good light.

Gas lamps with a broad, open flame make light in the same way as the oil lamp, namely, by the glowing par-



CANDLE FLAME

*A*, combustible gases from the melted candle. *B*, bluish flame. *C*, luminous flame. *D*, hottest part of flames, almost invisible.

ticles of carbon during their oxidation. The gas lamps which use some type of the Bunsen burner have a mantle over the flame. The Bunsen burner mixes the oxygen of the air with the gas before it gets to the flame, and complete oxidation of the carbon particles occurs so quickly that not much light is produced, but a very hot flame results. This flame brings the white mantle to a glowing white heat and a very bright light is produced. The Bunsen burner can be used for burning gasoline, acetylene gas, or natural gas.

Incandescent electric light bulbs make light because the fine wire, carbon, or tungsten filament in them is made white-hot by the electric current passing through. In the street corner arc light a glowing arc of white-hot carbon vapor and the glowing ends of the carbon make the light. There are two sticks of carbon in the lamp, and after the current is turned on the ends of the carbon are automatically pulled apart and then the electric current crosses from one to the other by vaporizing the carbon. While the carbon is being vaporized, it is made white-hot. The arc lamps can be made to give a light of 500 candle power.

**200. Illuminating Substances.** — Candles are made of tallow, sperm whale oil, or paraffin, by dipping the wicks into the melted oil or by pouring it into molds containing the wicks.

Carbon oil and gasoline are made by distilling crude petroleum. Paraffin is also obtained from petroleum.

Natural gas is obtained by drilling into the earth in the same manner as for petroleum and then collecting the gas in storage tanks, from which it is piped to buildings for heating, cooking, and lighting. Natural gas is not very widely distributed and its use is largely restricted to the regions where it is found.

Artificial or coal gas is made by heating coal in furnaces where air or oxygen cannot get to it. The gas comes from the coal containing many impurities which are removed by washing the gas, that is, by passing it through water and other substances; the pure gas is then collected in tanks for use. The by-products which come from the production of coal gas are ammonia, coal tar, carbolic acid, naphthalene, and anilin dye. Coke is the residue left after the gas is driven out of the coal.

Acetylene gas is made by allowing calcium carbide crystals to fall continuously into a tank containing water. The tank is air-tight and so arranged that the inside part can move up and down according to the gas pressure. The gas is distributed through pipes to the burners. In acetylene gas lamps the water is permitted to drip into the can containing the calcium carbide. The carbide is made by fusing coal and lime together in an electric furnace. Slaked lime is the residue left after acetylene gas is made by the action of water on the carbide.

#### QUESTIONS AND EXERCISES

1. Give the history of the development of artificial lighting.
2. How are oil and gas obtained for lighting?
3. Have oil and gas always been used?
4. Explain how a gas flame makes light.
5. Explain how an electric lamp makes light.
6. What are the substances now used for lighting?

## CHAPTER XXX

### SOUND

**201. Personal Experiences.** — We have not been in this world very long before we have been attracted by a sensation received through the ears and have also attracted the attention of those about us by our voices. We grow able to produce sounds which are loud or soft according to our wish. When we gain the ability to carry a tune, we are able not only to distinguish one tone from another as having a different pitch, but also to produce tones of a different pitch. We then soon learn to note the difference in the character of a tone produced by a piano and a violin, a violin and a guitar, or a piano and the human voice. We discover the echo as we walk heavily in a large hall or speak loudly when at the proper distance from a large building or steep hillside.

During early youth we discover that the shrill whistle of a locomotive or other steam engine is produced by the emission of steam, and if we are at some distance from the locomotive we see the steam a few seconds before we hear the whistle; so we conclude that it requires time for sound to travel over the space between us and the locomotive. The time arrives when we no longer have any difficulty in distinguishing between a noise and a musical sound; and when several tones of different pitch are sounded together, we soon decide whether the effect is harmonious and pleasant or whether it is a discord.

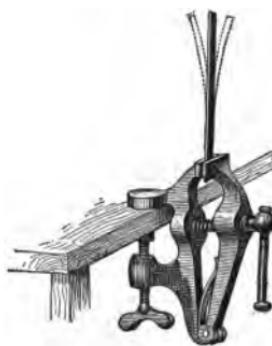
The foregoing are some of the experiences that we pass

through while growing from childhood to maturity. It is the aim of this chapter to present some definite ideas concerning the nature and cause of the experiences which we have had. We have found that we can not only distinguish sounds from each other, but that we can also ascertain the direction from which most sounds come. The ability to determine the direction enables us to locate the source or the cause of the sound. Every time we look for the cause we find some vibrating body or an object that has been vibrating.

**202. Sound Caused by Vibrations.**—When the bow is drawn across one of the strings of a violin, that string will emit a tone and it can be easily seen that the string is moving or vibrating back and forth

very rapidly. The string has a hazy appearance because the eye can detect only about ten separate objects or motions per second. The violin string vibrates many times ten per second and so appears to have a hazy width. If a piece of steel or a ruler is clamped in a vice or held firmly on the edge of a desk and then made to vibrate, a tone will be produced. That the ruler is vibrating can easily be seen. When the vibration ceases no sound can be heard. The

prongs of a tuning fork also look hazy at the end when a tone is given out. To prove that the fork is vibrating when it emits a tone, touch some water with the ends of



VIBRATIONS OF A ROD

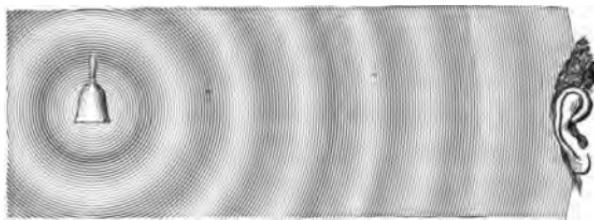


TUNING FORK

The vibrating fork throws the water.

the prongs, as shown in the illustration, and see if the fork throws the water. From these tests we can conclude that: *Sound is caused by a vibrating body.* If the strings of a violin, guitar, or piano are struck, a sound is made. If an explosion of gas or powder occurs, the air is made to vibrate and we hear the sound. If a book or pencil falls on the floor, the floor is made to vibrate and a sound is produced. If some one taps on the door, desk, table, or even the brick wall, these objects will be made to vibrate and a sound may be heard.

**203. Transmission of Sound.**— Every part of our body is sensitive to the vibratory motion of a solid body which



SHOWING SOUND WAVES IN THE AIR

touches us; but our ears are the special organs for detecting sound, and they are sensitive to very slight vibratory motions. No sensation of sound can be received unless the inner parts of the ears are disturbed by a vibrating substance. Since air touches our ears all the time, it is the most common substance which carries the vibrations of a distant object to us. But air is not the only substance that will carry sound. The Indians put their ears to the ground to hear a distant noise. An approaching train can easily be heard by placing the ear or teeth on the steel rail of the track. The sound of the electric car is carried by the trolley wire. If two stones are struck together under water, the sound can

be heard a considerable distance away by a person whose ears are in the water. These facts show that sound can be carried from its source to the ear by solids, liquids, or gases.

**204. Speed of Sound.**—In our rooms during conversation we might suppose that sound travels instantly from one person to another. But when we see the condensed steam from the whistle of a locomotive evaporate or become invisible before we hear the sound, we know that sound does not travel instantly. If we see a flash of lightning, it is sometimes several seconds before we hear the thunder.

The French Academy of Science appointed a commission in 1832 to determine the speed of sound. They placed cannon on two hilltops that were 11.5 miles apart. The cannon were fired at night so that the flash could be seen, and the time was determined from the time the flash was seen till the sound was heard. This commission found the speed of sound to be 331.2 meters per second, when the air was at freezing temperature or  $0^{\circ}$  C. The accepted rate for the speed of sound is 331.3 meters, or 1087 feet, per second at  $0^{\circ}$  C. The speed of sound in water is 1400 meters per second, or about four times the speed in air. The speed in iron is 5100 meters per second, or about sixteen times the speed in air.

The speed of sound in air increases with an increase in temperature. The amount of this increase is about 60 centimeters, or two feet, per second per degree centigrade. So the speed of sound at  $20^{\circ}$  C. is 40 feet per second more than at  $0^{\circ}$  C., or the speed at  $20^{\circ}$  C. is about 343.3 meters, or 1126 feet, per second.

**205. Reflection of Sound.**—An echo is a reflected sound. All solid objects reflect sound just as nearly all

reflect light. The objects which diffusely reflect light we can see, while those with smooth surfaces, like a mirror, reflect light so perfectly that we see images of objects instead of the mirror itself. In a sense the opposite is true with sound. The objects which are so rough that they reflect sound diffusely do not make an echo, because the sound wave is broken up and reflected in all directions to such an extent that no distinct wave returns to our ears. Buildings and most rock cliffs and steep hillsides are smooth enough to reflect sound and make an echo. If we make a loud sound about one-eighth of a mile from a large building or hill, the echo will be heard in about a second.



SOUND REFLECTOR FOR AN ORCHESTRA

If we are only fifty feet from the reflector, we will not get a good echo because the sound wave will return in less than a tenth of a second. The human ear cannot distinguish more than about ten distinct sounds per second. If eleven or twelve sounds per second are made, they will seem to the human ear like one continuous sound.

In a hall or large auditorium the speaker's voice is reinforced by the reflections of the sound from the walls. Since the reflected sound and the sound direct from the speaker's voice strike our ears so nearly at the same time, we are unable to distinguish any echo, but we get a louder sound than if there were no reflection. A speaker in the open air must talk with a much louder voice than in a

building, or he could not be heard very far. Why? Sometimes auditoriums are built in such a form that the walls reflect the sound back and forth, and the sound waves from the speaker are so disturbed that he cannot be heard distinctly. This defect of auditoriums can be remedied sometimes by stretching wires across the hall or by hanging draperies, or by moving the stage toward the audience.

Sometimes an echo is produced when a sound wave passes from one layer of air to another layer of greater density. Sound will also be reflected when it passes from one current of air into another current going in the opposite direction. The rumbling noise following a thunder-clap is due to the reflection of the sound by the clouds and air.

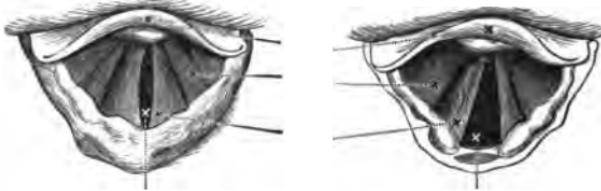
#### QUESTIONS AND EXERCISES

1. Recall all your experiences with sound and write what you know about it.
2. How is sound made?
3. How is sound carried? How fast?
4. Can sound be reflected?
5. Explain the echo.
6. What practical use is made of sound?

## CHAPTER XXXI

### VOCAL CORDS AND THE EARS

**206. Vocal Cords.**—The vocal cords are the organs which produce sounds for speech. They are two tough, elastic bands, stretched across the upper end of the windpipe, and their ends are attached to the cartilage of the larynx (Adam's apple). These cords can be ren-



Cords stretched for singing.

Cords as they are for breathing.

HUMAN VOCAL CORDS

dered more or less tense by muscles which by contraction can move the pieces of cartilage. When we speak or sing, these muscles stretch the cords and make the passage between them small, so that when the air from the lungs is forced out between the cords, they vibrate and produce sounds called the voice. The pitch of the voice depends upon the number of vibrations per second of the vocal cords. When these sounds are modified by certain positions of the tongue, palate, teeth, lips, and nose, so as to form words, speech is produced.

The vocal cords are longer in men than in women and therefore women have a voice of higher pitch. The longer and thicker the cords are, the less frequently they vibrate

when air is forced out between them. Because of this difference between the vocal cords of men and women, men cannot sing such high notes as women, and women cannot make the low tones of the bass. A man's voice is about one octave lower than a woman's voice. The voice of a boy has the same pitch as that of a girl. A boy's voice drops one octave between the ages of 14 and 18 years. The difference between a soprano and an alto voice is merely one of length, tension, and thickness of the vocal cords. The difference between a tenor and a bass voice is caused by the same variations.

The loudness of the voice depends upon the force with which the cords vibrate, and this depends upon the force with which the air is expelled from the lungs when passing between the cords. While whispering the vocal cords are so far apart that the small amount of air passing through does not make them vibrate, but the current of air is checked at intervals and modified by the organs of speech.

**207. The Voice.**—The quality of the human voice is determined principally by the condition of the chest, windpipe, mouth, and nose. The air in these organs is caused to vibrate by the vocal cords. The nasal twang is produced when the nasal passages are partly or completely closed by a cold or by a growth of tissue called adenoids. Hoarseness is due to a swelling of the cords, resulting from the blood and lymph (a colorless liquid) collecting in them because of a cold or too-long-continued use. To train the voice, then, is to remove all these needless obstructions, to learn how to control the action of the cords and make them respond at will, and to develop the resonant parts so that the qualities of beauty and clearness will be gained. It is important that everyone should cultivate a smooth and pleasant tone of voice.

The mouth should be well opened while speaking or singing, the soft palate elevated, and the lips moved with firmness. A mouth-breather can never develop a clear, sweet voice, because the vocal cords are affected by the

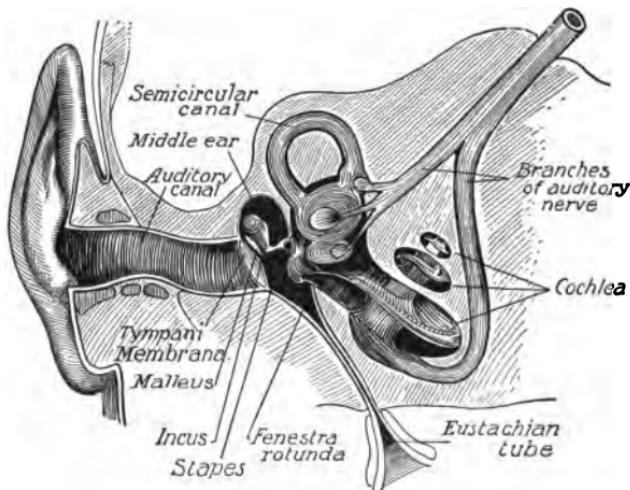


DIAGRAM OF SECTION THROUGH THE HUMAN EAR

cold air and dust which reach them by such breathing. A person who has not learned to breathe through the nose cannot sing or speak very long without becoming hoarse. The teeth also play an important part in singing and speaking by their resonant and modulating effect. To have a good voice for singing, good teeth are usually necessary.

**208. The Ears.**—The ear consists of three principal parts, namely, the external ear, the middle ear, and the internal ear. The external ear, which is visible on the side of the head, is more or less folded so that it can catch the sound waves and reflect them toward or into the ear-tube, called the auditory canal, which is about an inch long. The inner end of this canal is closed by a membrane called the tympanic membrane or ear-

drum. The ear-drum is a thin, membrane-like muscle which vibrates when a sound strikes it.

The *middle ear* is separated from the external ear by the ear-drum and is connected with the throat by a tube called the Eustachian tube, through which air can pass in and out of the middle ear. Air comes out of the Eustachian tube when the air pressure in the outer ear decreases, and air goes into the tube when the air pressure outside increases. The purpose is to keep the air pressure in the middle ear the same as in the outer ear, in order that the ear-drum may keep its position and not bulge in or out, or be burst. The middle ear also has three small bones called the hammer, anvil, and stirrup, which form a chain from the ear-drum to a membrane closing an oval opening into the internal ear. These bones transmit the vibrations of the ear-drum, caused by sound waves, to the membrane of the inner ear.

The *inner ear* is composed of several irregular connected cavities. The three semicircular canals, at right angles to each other, have nothing to do with hearing, but enable the body to keep its balance and know its position even with the eyes closed. The coiled part of the inner ear, called the *cochlea* because it resembles a snail shell, contains a watery fluid and also the ends of the nerves of hearing. This fluid, when disturbed by sound waves, affects the hair-like parts which connect with the nerves.

**209. Hearing.**—When an explosion or a vibrating body produces a sound wave, the outer visible part of the ear reflects the wave into the auditory canal. The ear-drum is made to vibrate and the three bones in the middle ear carry this vibratory motion to the membrane of the inner ear. The liquid in the inner ear transmits the vibrations to the hair-like projections of the cells containing the

nerves of hearing. The nerve fibers unite to form the auditory nerve which carries the stimulus to the brain. The brain interprets it in relation to loudness, quality, pitch, the direction from which it came, and the distance of its origin. From these characteristics, in the light of previous knowledge and experience, the origin and cause of the sound may be ascertained.

**210. Care of the Ears.**— Hard objects, such as pencils, toothpicks, and matches, should not be pushed into the auditory canal of the outer ear for fear of puncturing the ear-drum. The wax, which keeps insects and dirt out of the ear, sometimes collects in too large quantities and hardens in the canal. It can be removed with the round end of a hairpin by being careful not to shove the hairpin in more than about three-fourths of an inch. The hardened wax can also be softened by the use of warm water and then easily removed. A person should never be struck upon the ear with the open hand, because the ear-drum may be injured by the air which is suddenly forced into the auditory canal by the swiftly moving hand. The Eustachian tube is sometimes closed at the throat end during the time when a person has a cold, and then the air pressure in the middle ear cannot be kept the same as it is in the outer ear; this may result in the rupture of the ear-drum and deafness may follow. To keep the ears in good condition one should guard against all nose and throat diseases.

#### QUESTIONS AND EXERCISES

1. Where are the vocal cords? Of what use are they?
2. What parts of the body affect the voice? How is nasal speech produced?
3. Name the parts of the ear and the use of each.
4. How do colds and throat diseases affect the ears? How should you care for the ears?

## CHAPTER XXXII

### THE SOIL

**211. The Soil** is the surface of the earth which contains the necessary compounds and characteristics for the growth of plants. It varies in depth from a few inches to many feet, according to the method of formation and the amount of erosion that has taken place. It can be increased in depth by the growth of vegetation and by proper cultivation.

**212. Origin.**—The surface of the earth at one time was barren rock, unfit for plant or animal life. It was much like the surface of cooled lava which flowed from volcanos. There are yet in the Rocky Mountain section large areas of almost barren rock which are not suitable for cultivation. Some other parts of the earth are covered with vast lava flows which cannot be cultivated, and no plants of any kind can grow on them.

The surface of the rock which ages ago covered the earth was gradually broken up or decomposed by the action of water, air, and the changes of temperature from one season to another. The oxygen of the air oxidized the iron and certain other substances that it could reach, and the water made it more favorable for this oxidation to occur. You know that iron if wet will rust rapidly, that is, it will oxidize. The water dissolved parts of the rock and carried insoluble particles into localities where they were deposited with the soluble parts left by the water when it evaporated. The expansion and contraction of

the rock caused by the changes in temperature made the rock crumble into fine particles. The freezing of water in the rock greatly assisted this crumbling process.

Small quantities of this disintegrated rock collected in various places and made it possible for the lowest plant forms to begin life. The decomposed rock contained the necessary chemical elements for primitive plant growth.



BENEATH THE SOIL IS ROCK

As these simple plant forms grew to maturity and died, they added decaying plant matter to the forming soil. This decaying matter, as soon as it became soluble, served as food for other plants. Then came a process of plant changes, or the evolution of plants. As plant food became more abundant, the simple plants grew larger and more complex in their structure. They decomposed the rock with their roots, took food from the air with their leaves, and then in turn died and decayed; thus the soil was increased in depth and richness. This process continued for ages, and now the larger part of the land surface of the earth is able to support plant life of some type. Since man has been growing plants for food many rich

soils have been ruined by ignorance and carelessness. In recent years farmers have begun to learn how to make soils productive and how to keep them fertile.

**213. Physical Composition of the Soil.**—In the preceding section is given the origin of two of the important parts of a productive soil. The greater portion by weight of most soils is composed of decomposed rock or rock particles, but no crop could grow on a soil composed en-



A HILLSIDE PROPERLY CULTIVATED TO PREVENT EROSION

tirely of disintegrated rock. A soil which is suitable for agricultural purposes is made up of five important parts, namely, (1) disintegrated rock, (2) soil water, (3) soil air, (4) humus or decaying organic matter, and (5) bacteria and other living organisms.

Not many kinds of crops can be produced in soil which lacks any one of these five parts. Much soil which is found in some swampy regions is made up largely of decaying organic matter. It is valuable for growing onions and celery. Soils that do not have the proper amounts of water, air, bacteria, or humus, will not grow large crops.

**214. Disintegrated Rock.**—All rock on the earth was at one time igneous like that which flows from active volcanos. This igneous rock was acted upon by the heat of the sun, by water, and by the air until it was broken up so that the flowing water could carry the finer particles and some in a soluble form. These deposits of disintegrated rock made by the water sometimes became deep enough so that they turned into solid rock again. The rock dissolved in the water served to cement the sand and gravel together the same as when cement is used for making concrete.

Sand rocks were made mostly of sand cemented together. The kind of sand rock was determined largely



LIMESTONE MADE OF SHELLS

by the size of the sand grains and their chemical composition. Lime rock was formed from the shells of water animals. At one time these animals with shells for protection were more numerous than any other kind, and as they died their shells formed deposits many feet deep in the part of the ocean in which they lived. After many feet of sand and clay were deposited on the top of these shells they were pressed together so solidly that they formed stone, which is our present limestone. Limestone could be made of oyster, clam, and muscle shells because they have the same chemical composition as limestone. Chalk is a form of limestone made of very small shells of animals which lived in the water by millions. If chalk

dust is placed under the microscope the individual shells can be seen. The extensive chalk deposits in the United States and England were formed of these tiny animals.

The marble of the New England States was made by the limestone deep in the earth being heated to a certain temperature and then cooled; afterward the sand rock on top of it was washed away and the marble was exposed to view and now man can quarry it for building purposes.

The formation of sand rock from water deposits, limestone from deposits of shells, and with a deposit of clay occasionally between the rock layers, has gone on for millions of years, so that now rock strata formed of water deposits are many miles deep. During all these past ages the earth was being prepared for the habitation of man, who has now studied the structure and composition of the various kinds of rocks and has learned their relation to soils and agriculture.

The disintegration of all kinds of rock near the earth's surface is still going on and soil is being formed. By a knowledge of the kind of rock on the surface in any locality, one can tell much of the nature of the soil and what should be done to make it fertile and keep it productive. A region that has limestone near the surface is usually very productive, while the soils in sandstone regions are not very fertile. It is very expensive to make sandy and clay soils fertile in a hilly or rolling country;



CHALK  
Magnified.

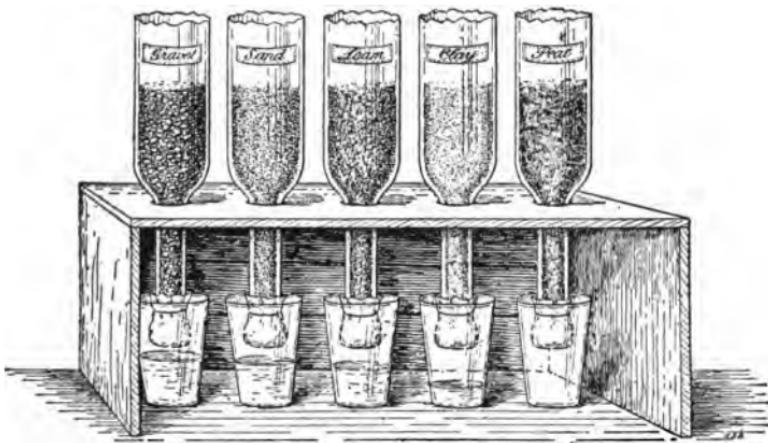
but a soil made of a mixture of sand and clay in low ground or in river valleys can easily be kept productive.

The disintegrated rock particles in most soils make from 60 to 95 per cent of the soil's weight. The size of the particles usually determines the nature and productiveness of a soil. A coarse-grained soil cannot retain much water, and the spaces between the particles are so large that the air can move about in it so freely that much of the soil water is carried out by evaporation. This is very noticeable when broken soil is not pulverized before a dry season. Finely divided soil will retain the water better. But soils which hold a large quantity of water will not become warm enough for the growth of plants early in the spring. The best soil for general purposes is, therefore, one composed of a mixture of coarse and fine particles.

**215. Soil Water.**—Soil water is not all the water that is in the ground, it is only the water which adheres to the soil particles, like the film of moisture which adheres to an object when it is dipped into water. When soil is moist and will not pack if you squeeze it in your hand, each particle of it has a film of water around it. The film of water is what the roots of plants absorb for food. This soil water has the plant food dissolved in it.

The productiveness of a soil is usually determined by the amount of soil water which the soil can hold and by the ease with which the roots of plants can get to this soil water to remove it. For this reason it is very important that the excess of water should drain away during a wet season so that the roots of plants can have more soil particles from which to get food; and in dry seasons the soil water should not be permitted to escape from the surface by evaporation. Excess water during a wet sea-

son can be drained away by tiling, and evaporation during a dry season can be prevented by shallow cultivation, thus forming a dust mulch. Deep cultivation during a wet season will help to remove water by evaporation. The farmer who learns how to keep the proper amount of moisture in his soil is the one who is successful in growing large crops.



APPARATUS TO TEST THE CAPACITY OF SOILS TO HOLD WATER

During dry weather the water deep in the ground comes toward the surface by moving from one particle of soil to another, the same as it travels upward in a lump of sugar or a cloth. Such a movement of water is called movement by capillarity. This upward movement is often necessary for seeds sown on the surface, so that they may keep moist and grow. Capillarity is assisted by running a roller over the ground, which crushes the clods and packs the surface. This keeps the seeds moist, but the water escapes by evaporation. Sometimes the soil is packed just over the seed, when one or two rows are planted at

a time, as is done by the corn planter, the wheels of which press the soil around the grains of corn.

Some lands are too dry for cultivation, and so they are irrigated by digging small canals through which the water flows and seeps out into the soil, from which the plants take it and the food that is dissolved in it.

**216. Soil Air.**—About half the volume of ordinary soils when they are dry is air. A cubic foot of dry soil contains about half a cubic foot of air. Take a known quantity of dry soil, say one peck, and see how much water can be poured into the vessel containing it. As the water goes in the air comes out of the soil, and hence the quantity of water poured in will be the measure of the air that was in the dry soil. From this it can be seen that, as the water in soils increases, the amount of air decreases, and that when soils are saturated there is very little air in them. Soil air is just as necessary for the growth of farm crops as it is for the life of animals. When water excludes all the air from the soil, the crops will suffer and drown just as surely as a person drowns in water, but not so quickly. This is very noticeable when river valleys are flooded late in the spring. Corn in fields that were under water for a few days has a yellowish color, while much of the corn dies if the soil is covered with water for a week or more. Plants turn yellow when too much water is in the soil, because they cannot then get a sufficient amount of the element nitrogen which is necessary for the making of green coloring matter in the leaf. Plants are not healthy without this green coloring matter. Air is also necessary for the growth of bacteria in the soil. The bacteria decompose the humus and leave it in soluble form for the plants to absorb with the soil water.

Fine clay-loam soils contain more space for air than coarse sandy soils because they do not pack so closely, the particles being light. But the air spaces in sandy soils are larger than in finer soils, and this allows the air to move about so freely in coarse, sandy soils that too much water is lost by evaporation. Thus we see that too much air in the soil is not good. Coarse soil is usually too well aerated or aired and also too well drained.

There are some marsh plants that can grow in standing water. Rice is one of them, but the common farm crops could not thrive under such conditions. Even rice requires some air in the soil, the same as water lilies and submerged seaweeds, but these plants are able to get air from the water. Ordinary water has a large quantity of air dissolved in it.

**217. Humus.**—Humus is the decaying plant and animal matter of the soil. It is composed of the roots and stems of dead plants and of animals which died in and on the soil. Humus is organic matter and gives most soils a dark color. It is necessary for the growth of good crops, but the common seed-plants cannot live directly on humus. Plants can take food from the soil only in soluble form; they cannot absorb humus, but they can take up the soluble compounds which come from decaying humus. In order to have plant food in sufficient quantity in ordinary field conditions, it is necessary to have humus decaying continuously. If the humus decays too rapidly, the plants cannot use all of it and part will be wasted. If the humus decays too slowly, there will not be sufficient food for the growing plants and the crop will be small. Plants may be grown in moist sand if all of the food elements are supplied, but this is a difficult process.

Humus serves several other good purposes besides

supplying plant food when it decays. It increases the capacity of soils for holding water, which is very important in sandy soils and especially during dry seasons in all soils. The decaying humus is porous and acts somewhat like a sponge in holding water. This can be illustrated by taking equal volumes of sandy soil and soil with a large quantity of leaf mold from the woods; place the two soils under the same conditions, moisten them thoroughly, and see which will hold the more water and which will stay moist the longer. (See page 311.) Humus loosens heavy soil and makes it possible for air to penetrate more deeply and freely; this is particularly important in clay soils, as they are usually heavy and compact. It furnishes food for bacteria which change nitrogen to dilute nitric acid so that plants can use it for food. Decaying humus liberates carbon dioxide (carbonic acid gas) which acts on the minerals of the soil and makes them soluble for the use of plants. Humus also makes it more favorable for those bacteria to live which take free nitrogen from the air and leave it in the soil in the form of nitrates which can be used for food by the plants.

A moderate amount of moisture and air makes the normal condition for the decay of humus at such a rate that plants will receive the proper supply of food. If the soil is too well aerated, the humus will decay too rapidly. If the soil is saturated with water, most of the air will be excluded; then the decomposition of humus practically ceases, organic matter accumulates, and there is no plant food available. Examples of this can be found in swamps where peat and muck are formed.

Soils that receive a moderate rainfall have about four times as much humus as soils in arid regions. But the humus in soils of arid regions decays much more rapidly

than in moist soils, and it also contains a larger percentage of nitrogen, so the plants receive the proper supply of food in either case. The light color of soils in arid regions is due to the lack of humus and not to the lack of plant food. Dark soils sometimes lack one or more important elements of plant food. This must be supplied before large crops can be grown.

**218. Bacteria and Other Living Organisms.**—Soil is not an entirely dead substance. It is much more than a collection of rock particles containing some water. It is full of life, and without this life the valuable grains and vegetables could not be grown. In order to keep the soil productive it is necessary to keep the helpful living organisms in the soil healthy and well supplied with food. Some of these living organisms are animals, but most of them are the lowest forms of plants, such as molds, and the one-celled plants such as bacteria and yeast. Some bacteria live on the waste products of molds and other bacteria, and thus the plant food is worked over and over until it finally becomes available for use in proper form. If there is not enough humus, or if the humus is not properly decomposed by the living organisms, the growing plants will suffer and small crops will result.

Molds are very effective in breaking down woody organic matter. The root-like portions of the mold soften the woody tissue of plants and then bacteria can work on it with good results. The effects of mold can be seen by keeping some old bread moist for a few days at a temperature of  $70^{\circ}$  to  $90^{\circ}$  F.

Earthworms and a few other small animals help to work up the soil, decompose organic matter, and keep the soil porous by making holes as they travel through it.

Soil full of earthworms is usually fertile, as they feed on organic matter. The most important of all living organisms in the soil are the bacteria and yeast plants.

Bacteria are so small that they have to be magnified 500 or more times before they can be seen. It takes from 25,000 to 150,000 of them laid side by side to make an inch in length. But what they lack in size they make up in numbers and rapidity of reproduction. If they have all the food they need, and if the other conditions are right, there will be a new generation every fifteen to thirty minutes. They increase in numbers simply by one bacterium (singular of bacteria) dividing into two equal parts, each of which is a bacterium. If they divide every fifteen minutes there will be four generations per hour, and at the end of the hour there will be sixteen new bacteria from each bacterium. If enough food could be secured, the offspring of one bacterium during a period of four or five days would be sufficient to fill all the oceans of the earth. But a limited supply of food and unfavorable conditions for growth prevent this rapid increase of bacteria from continuing.

Bacteria of various kinds are found in all soils. They range from less than 30,000,000 per ounce up to billions per ounce of soil. The most fertile soils, like those in gardens, contain the most bacteria. Some experiments have shown that the soils which produce the greatest crops contain the most bacteria. Some soils will produce a large crop of one kind but will not produce a crop of a different kind. This is sometimes due to the absence of the bacteria that a certain plant needs. Some plants have specialized bacteria and will not grow without them. Alfalfa is such a plant, and if it does not grow the soil must be inoculated with alfalfa bacteria taken from the

fields where alfalfa has been growing. Two or three bushels of soil taken from an alfalfa field and scattered over an acre of ground are enough to inoculate it with alfalfa bacteria. Clover, beans, peas, and other podded plants have a special kind of bacteria which live in nodules on their roots. These bacteria in the nodules can take free nitrogen from the soil air and make nitrates which the plants can use for food.

"The different chemical changes produced by soil bacteria are quite numerous. Some kinds are specialized for one series of changes, others for changes of a different sort. Some will attack by preference carbohydrates like starch or sugar, some will decompose woody tissue, some will cause the decay of proteins, some of fats, etc. This division of labor allows an effective decomposition of humus. Various gases and acids are produced in the course of decay, and help to decompose the rock particles in the soil and to render the mineral plant food contained in them available. The insoluble protein compounds in the roots and stubble are broken down and their nitrogen changed partly to ammonia. The particles of ammonia, as they are thus generated by bacteria of many kinds, are at once pounced upon by a special class of germs whose function it is to change the ammonia into nitrate. Thanks, therefore, to the activities of many species of bacteria, the nitrogen



NODULES CONTAINING NITROGEN  
On the roots of a leguminous plant.

locked up in the humus and in green manure is transformed gradually into nitrate, and is then quite suitable for the building of roots, stems, leaves, and fruits." (From Bulletin of the U. S. Dept. of Agriculture.)

Bacteria are one-celled plants, and like other plants some are useful and others are harmful and cause disease. There are more than 1000 kinds of bacteria and only about twenty of this number are known to be harmful to man. The bacteria which cause tuberculosis, typhoid fever, lockjaw, and diphtheria are called disease germs and man must learn to keep himself healthy or these germs will decompose his body and death will result. Experiments have shown that certain bacteria in food and in the food-tube of animals are necessary for the existence of the animals.

**219. Chemical Composition of the Soil.**—All the chemical elements of which plants and animals are composed are found in the soil; most of them are in the disintegrated rock, and the others compose the greater part of humus. Humus itself contains a certain amount of the elements of plant food. Elements which are used by nearly all plants for food are potassium, sodium, phosphorus, sulphur, magnesium, silicon, calcium, iron, chlorine, carbon, hydrogen, oxygen, and nitrogen, and a very small quantity of a few others. These elements are not taken up by the plants in pure form. They are combined into numerous compounds and these compounds must be soluble before the plants can use them. The sulphates of calcium, magnesium, sodium, and potassium are all soluble in water, and they can be absorbed by the roots of plants. The nitrates also are soluble and very important as plant food.

When humus decays most of the carbon escapes into

the air in the form of carbon dioxide, and thus the plants are provided with a means of taking carbon dioxide from the air, breaking it up, and using the carbon to form compounds for building material. The leaves of plants are the organs which manufacture food of carbon dioxide and water. A large part of the body of plants is carbon. Of the elements which plants take from the soil, nitrogen is one of the most important; it is also the most difficult to keep in the soil and the most expensive of all plant foods when purchased in the form of commercial fertilizer.

About 79 per cent of the air is nitrogen — an inexhaustible supply for plants. But plants growing in the air would starve to death for nitrogen if they could not get it from the soil in the form of soluble compounds. *Plants cannot take free nitrogen from the air.* This being true, it is necessary that farmers learn how to keep a supply of nitrogen in the soil. The nitrogen compounds in the soil decompose readily and the free nitrogen escapes into the air. When humus decays soluble nitrates are formed, and if there are no growing plants to use these nitrates they will be broken up and the nitrogen will escape. One method of keeping the nitrogen in the soil is to keep a crop growing during the time when humus is decaying, and to have on the ground in winter a cover crop of some kind which will hold the nitrates and prevent them from being leached out by the water. These cover crops can be plowed under in the spring and will then form humus.

There are four practical ways of getting nitrogen compounds into the soil when they are deficient. *First*, by growing weeds, rye, or other rapidly growing plants and plowing them under while green but almost mature. *Second*, by growing clover, cow peas, or some other legume. If several crops of legumes are plowed under,

the soil will be well supplied with nitrogen. *Third*, by covering the soil with manure which is composed of animal excreta and waste from the stems of plants, and plowing it under. Every kind of decaying organic matter has nitrogen in it. *Fourth*, by buying nitrates in the form of commercial fertilizer and sowing it on the soil; this is usually done by sowing it with grain seed in order that it may help to produce a crop without much waste.

The other elements of plant food that are often bought as fertilizers are potassium and phosphorus. Phosphorus is purchased in the form of phosphoric acid and potassium as potash or muriate of potash. Nitrogen is sometimes purchased in the form of ammonia. The nitrogen, potassium, and phosphorus compounds are usually mixed in known proportions and sold as commercial fertilizer.

#### QUESTIONS AND EXERCISES

1. Give the history of the formation of the soil.
2. Name the parts of good soil.
3. How does the weather affect rock lying on the surface?  
Does rock contain food for plants? Explain.
4. What is meant by soil water? How can it be retained for plant use?
5. How much of the soil is air by volume? Prove your answer by an experiment.
6. Is there any decaying material mixed with the soil? Of what use is it?
7. Of what use are living organisms in the soil? Could plants grow without them? Explain.
8. Which plants protect soil bacteria?
9. Which method of keeping the soil supplied with nitrogen is the cheapest? Why?

## CHAPTER XXXIII

### HOW TO CARE FOR SOIL

**220. Value of this Knowledge.**— Since man is directly and indirectly dependent upon the soil for his food, it is important that he should learn as much as possible concerning the nature of soil and how to care for it in order that he may be able to keep it in good condition for the production of large crops with the least amount of labor. The animals which man uses for food live upon plants which are produced by the soil; this is the indirect dependence of man upon the soil for food. The production of beautiful flowers, lawns, and trees also requires a knowledge of the soil. In order to grow house plants successfully one should know what kind of soil is best for them, and should also know how to keep the soil in flower pots in good condition. Every boy and girl should know how to care for plants in the house, or in the garden, or on the farm; in order to be able to do this it is necessary to know something of the nature of soil and when and why plants are cultivated.

**221. When to Cultivate.**— There are three principal types of soils, namely, clay soil, sandy soil, and loam soil. Clay is disintegrated rock almost as fine as flour. Clay soil holds a large quantity of water and if it is plowed while wet, during clear weather the sun will bake it and make hard, dry clods. Hence it should never be plowed or stirred while wet enough to form a ball when squeezed in the hand. Clay soils need to be handled with greater

care than any other kind, especially with respect to moisture at the time of cultivation.

Sandy soil is composed mostly of sand through which the excess water soon passes by filtration, leaving it dry enough to be plowed in a short time after a rain. Sandy soil will not bake or pack like clay soil and for this reason it is more easily cared for, although it is best not to plow it when too wet.

Loam soil is composed of a mixture of clay and sand. A sandy loam has a large per cent of sand, and a clay loam has more clay than sand. Loam soils are the best because the clay in them prevents the water from escaping too rapidly and the sand prevents the soil from packing and from being baked by the sun. Loam soils can be plowed when more moist and when dryer than clay soils, but it is best not to plow loam soil if it balls when squeezed in the hand.

Soil in gardens, flower beds, and flower pots should be stirred when it is moderately moist and will not adhere to a great extent to the tool being used. Plants in flower pots will do better if the soil is loosened occasionally before watering them.

**222. Why Cultivate Plants?** — In primitive times the soil was plowed or stirred in order to dispose of undesirable vegetation or weeds so that the desired crop might not be hindered in its growth. Cultivation for this one purpose was practiced for several thousand years and up to very recent times. Some farmers who are not acquainted with the nature of the soil still think that they cultivate principally to destroy weeds. The growth of weeds has been a benefit to man because they required the crops to be cultivated and thus the soil was made more favorable for the growth of the desired plants.

Under modern methods of progressive farming the destruction of weeds is merely a secondary matter, while keeping the soil in a favorable condition for plant growth is the principal reason for cultivating it. Besides the destruction of weeds, the following are the chief objects in the proper cultivation of the soil:

- (a) To loosen the soil for planting seeds.
- (b) To remove water during wet seasons.
- (c) To retain water during dry seasons.
- (d) To get air into the soil.
- (e) To cause the decay of humus.

Soils are plowed and pulverized so that the seeds can be planted at the proper depth and easily covered. It is also easy for the young plants to grow to the surface and for the roots to find food in a properly prepared soil, thus giving the young plant favorable conditions for rapid growth. In gardens the soil is prepared for the seed by use of the spade, the hoe, and the rake. On western farms large gang-plows, followed by drags and harrows, are drawn by steam or gas traction engines.

While the crops which need cultivation are growing, the excess water during a wet season can be removed by deep cultivation, because this permits much air to mix with the soil and also exposes the lower soil to the open air, allowing a large amount of water to pass off by evaporation. Care must also be taken in order not to cultivate when the soil is too wet, or both the crop and the soil will be injured.

During dry seasons the water can be kept from evaporating from the soil by very shallow cultivation. Several shallow cultivations during a dry season make dust of the surface of the soil. This dust prevents the water from escaping by evaporation. During dry seasons

water comes to the surface from several feet below and this water is usually sufficient to grow a good crop if it is not permitted to escape by evaporation. In gardens during dry seasons the surface should be raked lightly just after each little shower, so that the surface will not crack. Soil which is not pulverized on the surface and is permitted to crack will dry out very quickly.

About one-half the volume of ordinary soil is air. This is called soil air, and it is very necessary for growing plants. Cultivation keeps the soil loose and makes room for air, which occupies all the spaces between the little lumps or particles of soil. Soil that is very wet does not have much room for air and most plants do not grow well in it. As excess water is removed air enters.

Good soils contain a small percentage of decaying plant matter and some animal matter. This plant and animal matter is called humus. It is decomposed and made soluble by the action of microscopic bodies called bacteria and also by small animals living in the soil. These bacteria and small animals cannot live in the soil if there is too much water or if there is not enough water in it. They also need air. Proper cultivation is necessary to make conditions favorable for the growth of these organisms in order to make food available for the growing plants.

**223. Soil in Flower Beds, Pots, and Hotbeds.**—The soil for flower beds should be enriched with a well-balanced commercial fertilizer and some manure or with a large quantity of well-decayed manure. This manure should be thoroughly mixed with the rest of the soil. The soil should be cultivated often enough to keep it loose and well aired or aërated. During dry seasons sufficient water should be added to keep it moist but not wet.

The soil in flowerpots should be about the same as in flower beds. The pot should have a hole in the bottom to drain off the excess water. The soil should be kept moist by applying a little water daily. If the soil is too dry, the leaves of the plant will wilt; if the soil is too wet, the leaves will turn yellow. The soil in the pot should be loosened occasionally by digging it up with a stick. Do not use a sharp tool or the roots will be cut.

Hotbeds are made by digging a hole about sixteen inches deep and as large as desired. Put about twelve inches of manure in the bottom and then cover this with soil from four to six inches deep. The heat generated by the decaying manure warms the soil so that the seeds planted in it start to grow. The soil should be protected from the cold air by a box or board construction with a window sash for a cover. This glass cover is used to let in light and heat from the sun when it is shining. The heat from the manure and from the sun shining through the glass cover will raise the temperature of the soil so that the plants will grow rapidly.

**224. Soil Drainage.**—In hilly sections care must be taken to prevent the water from draining away too rapidly, or else the soil will be carried with it and in a short time what is left will become unproductive and unfit for use. By keeping the soil well supplied with humus and by keeping it covered with vegetation, the water from rains may be made to flow off very slowly; most of it will filter into the soil and then flow away as underground water.

In rolling districts the slopes are just about steep enough to carry away the excess water slowly, and usually no damage is done. It is not difficult to keep the soil on gentle slopes supplied with humus and vegetation and thus prevent surface erosion. Tiles placed in

the ravines will aid in carrying away surface water without damage to the soil.

In low lands where the slope is not sufficient to carry off the excess water, the farmers have to resort to artificial drainage. Some dig ditches every few rods, but these are a hindrance to extensive and free cultivation. The best method is to lay tile eighteen to twenty-four inches below the surface. The tile drains will carry away the excess

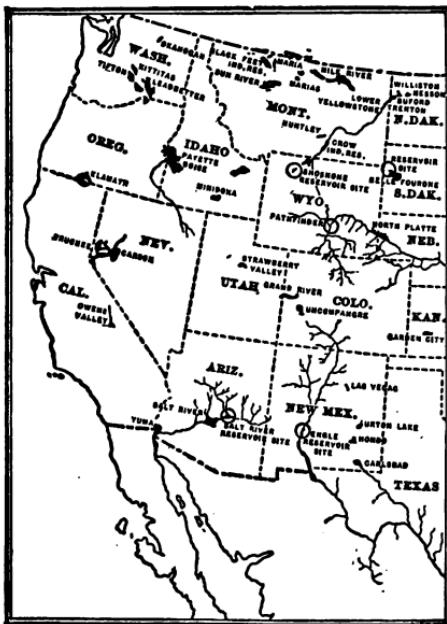


AN IRRIGATED ALFALFA FIELD

water and permit the air to enter the soil more freely and thus the soil will become more favorable for the growth of plants.

Much water is removed from wet soil by evaporation, but this keeps the soil too cold for rapid plant growth, because a large amount of heat is required to make the water evaporate. For this reason wet soils stay cold longer in the spring than soils which are well drained of their excess water.

**225. Irrigation.**—In regions where the rainfall is not sufficient for farm crops to grow, the farmers use artificial means of moistening the soil if sufficient water can be obtained at reasonable cost. Dams are built in moun-



## IRRIGATION PROJECTS OF THE U. S. GOVERNMENT

### Sites of dams and reservoirs.

it. Since the crops can be given water at the time when it is needed, larger crops can be grown than in many unirrigated districts where the crops have to depend upon rain for water. For this reason it is a good investment to spend money for irrigation. Even in the middle states some progressive farmers have a system of watering their vegetables and small fruits during long dry periods. Berries while getting ripe need a great amount of water, and often the crop can be doubled by having a small irri-

gation system to supply water when the needed rain does not come. Gardeners near cities use the city water and sprinkling hose to supply extra water.

The United States Reclamation Service under the Department of the Interior has reclaimed large sections of the desert land of the West by building dams in streams to hold the water so that it can be diverted from its



AN IRRIGATION CANAL IN ARIZONA

natural course to fertile fields where large crops are now being grown. The farmers pay from \$30 to \$60 per acre for their "water right."

The Roosevelt dam in Salt River, Arizona, is 280 feet high and 1080 feet long. It forms a lake of 25.5 square miles and will irrigate 190,000 acres of land. The Shoshone dam, Wyoming, is 328 feet high, 108 feet thick at the bottom, and only 200 feet long at the top. This is the highest dam in the world. The reservoir created by it has an area of 6,600 acres and a capacity of 456,000 acre feet; that is, it will hold enough water to cover 456,000 acres one foot in depth. Twelve miles below this

dam is the low diversion dam which turns the water through a tunnel  $3\frac{1}{2}$  miles long into the main canal, which can supply water for 164,122 acres of land.

The crops grown on the Shoshone lands are alfalfa, hay, wheat, oats, barley, potatoes, sugar beets, fruits, and green vegetables. Dairying and bee culture are also increasing, the products having a high market value.

**226. Effect of Sun's Heat on the Soil.**—The sun warms the soil so that it is possible for plants to grow; it also causes excess water to evaporate. While this evaporation is taking place rapidly, the soil is not warmed very much. If the soil is not properly cared for, the sun's heat will evaporate the water that should be retained for the crops.

If the soil that has a high per cent of clay, or is all clay, is plowed while wet, instead of moist, the sunshine will dry it so quickly on the surface that it will become very hard, and it is then very difficult to pulverize it, and it also often loses much of its fertility. Sandy soil, or soil with a large amount of humus in it, will not be easily baked by hot sunshine.

Clay soil, if it is not stirred on the surface after a rain, will dry hard and crack. These cracks, running in all directions over the surface, permit the soil water to evaporate rapidly and in a few days the crop will be suffering because of insufficient water. Clay soils should be stirred on the surface as soon as dry enough after each rain and the water will be held for the use of the crop.

**227. Erosion.**—Erosion is a wearing away of the land by the wind and water. You have seen clouds of dust in the streets of cities and on country roads or even in dry fields. This dust may not appear to amount to very much, but tons of solid matter are moved from place to place by strong winds, even in climates of moderate

rainfall. In places like western Kansas, where strong winds are usually blowing, much soil is moved by the winds just after the farmers have plowed their fields. Sometimes the soil particles and sand are flying in the wind in such quantity that clouds of dust can be seen from great distances. Along some of our seashores and lake shores, small hills of sand are made by the wind. These sandhills, called dunes, do not stay in one place,



EROSION IN A NEGLECTED FIELD

On a very gentle slope.

but move slowly in the direction of the prevailing winds. The sand is picked up on the windward side of the dune and then falls on the leeward side where the wind is less strong. On the shores of Lake Michigan these sand dunes move slowly eastward and sometimes bury valuable farm lands or even forest trees. The farmers try to prevent the movement of the dunes by planting shrubbery and making fences on the windward side so that the wind cannot pick up the sand and carry it to the opposite side.

In most parts of the United States the erosion caused

by water is much more noticeable than the erosion caused by wind. You can notice evidence of erosion during every summer shower. Water flowing on the street, or in ravines in the country, is made muddy by the small particles of solid matter that it is carrying. Ditches of various sizes on slopes and hillsides and the ravines through which the water runs were made by the flowing water and are evidence of rapid erosion. Most valleys are results of water erosion. The hills usually contain rock that is not easily decomposed and carried away by the water; for this reason they have remained longer than the earth that was carried away between them, but they, too, are slowly being carried away.

Water flowing in creeks and rivers, carrying sand, gravel, and at times stones that weigh hundreds of pounds, grinds the rocks in the beds of the streams into finer and finer particles, and also digs into the banks on either side. The water cutting into the banks of the stream causes it to widen its course and to flow back and forth across its valley; but a valley is not made until the bed of the stream is cut down to a comparatively low level. Make a careful examination of ditches on the hills or in the fields. Notice the influence of vegetation, such as grass, crops, or trees, on erosion. Observe the work done by creeks or rivers, and also the shape and width of the valleys.

Erosion caused by the waves beating against the shores of lakes and oceans is also very evident. The wind sometimes causes the water to form waves several feet high, and these waves beat against the shores and rocky cliffs, sometimes with tons of force, and the rocks lying at the base of a cliff are gradually ground to sand and carried out into deeper water.

The large quantity of earth moved by the process of erosion is not destroyed, but is deposited in various places for a time. The dust moved by the wind may fall anywhere. The fertile valley of a river is made of the soil carried from the hills and mountains. The slow moving water of a river is unable to carry with it the quantity of soil brought to it by its various tributaries. This solid matter is spread over the flood plain during each flood, and thus some of the richest farming land is made. Every river valley serves as an example of this rich soil deposited by rivers.

The very fine particles of solid matter are carried into lakes and oceans by rivers, and at the river's mouth they settle to the bottom or are carried far out by strong currents which pass the river's mouth. Deltas, such as those of the Mississippi and the Nile, were formed by the deposits of solid matter which the river carried to its mouth.

It can easily be seen that the hills and mountains are slowly but surely being worn away and carried into low lands and finally into the oceans. Some geologists say that the whole Mississippi basin is being carried to the Gulf of Mexico at the rate of one foot in 5000 years.

**228. How to Protect Soil against Erosion.**—We must not think of erosion as entirely harmful. The disintegrated rock of the soil contains some elements and compounds which are of no value to plants as food. Very slow and gradual erosion removes much of this undesirable waste material so that the roots of plants can get to new rock and find food.

When erosion goes on very rapidly much of the soil which contains plant food is carried away; this form of erosion is undesirable and should be prevented. The

method is very simple. It can be done by keeping the soil well supplied with humus and by keeping the surface covered with vegetation, especially during the seasons of the year when erosion goes on most rapidly. Large quantities of humus or decaying material absorb much water during showers and also keeps the soil loose so that excess water will sink and be drained off as underground



A CREEK BED

Filled with gravel and stone too heavy for the water to carry.

water instead of on the surface. Vegetation holds the water on the soil till it sinks in, and also prevents the formation of small streams. Moreover, it keeps the soil full of roots so that what little water runs off the surface cannot carry much soil with it. Crops like corn which need to be cultivated several times should not be grown on the same land many times in succession because continuous cultivation causes the humus to decay rapidly and these crops do not leave many roots in the ground to prevent erosion; hence a cultivated crop should be followed by a non-cultivated crop or several non-cultivated

crops, like wheat, grass, or clover. Slopes and hillsides need more care to prevent erosion than low lands, and many farmers have ruined much of their land by not guarding against erosion.

#### QUESTIONS AND EXERCISES

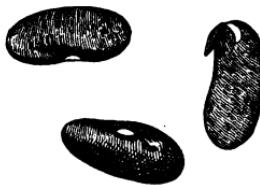
1. Why is it important to know how to care for soil?
2. What is the effect if soil is cultivated while very wet? If very dry?
3. What kind of soil is in your community? Does it dry out quickly? Why? What could be done to improve it?
4. Why do you cultivate the soil? How can moisture be retained in soil?
5. What kind of soil do you have in your flowerpots and flower beds? How should it be cared for?
6. What is being done to reclaim the desert lands of western United States?
7. What can be done to keep rains from washing away the surface soil? Is it a benefit or injury to have some of the soil washed away? Why?
8. How does sunlight affect soil? Is it better to have soil bare or covered with vegetation? Why?

## CHAPTER XXXIV

### HOW PLANTS GROW

**229.**—In order to be able best to care for plants in the home, in the garden, or on the farm, it is necessary to know a few things in detail concerning seeds, roots, stems, leaves, flowers, and fruits. If we know something of the structure and uses of each part of a plant and the conditions under which each part can thrive best, we shall be more successful in growing plants. To know the use of each part will also enable us to protect it from its enemies, such as insects and parasitic diseases.

**230. Seeds.**—Place a few beans (large beans will be best) in water for about twenty-four hours or in warm water for a few hours and then examine them carefully. The outer covering, consisting of a leather-like membrane, can easily be removed. After this covering is taken off the bean divides easily into two equal parts; each half is a seed leaf. At the end of one of the halves is a very small bean plant, with root, stem, and leaves. Two leaves are plainly visible; when the beans are planted the longer part of the young plant grows down into the ground and forms the roots. When this tiny bean plant starts to grow it needs food. This food is in the two halves of the bean. Beans are food for man and also for the young plant in each bean, when it grows.



KIDNEY BEANS

One is split open to show the embryo plant.

The bean contains chemical ferments which, under the influence of warmth and moisture, digest the stored food and make it soluble for the growing plant. We observed that the two halves are connected to the tiny plant at one end. Through this connection the digested food flows as the growing bean plant needs it.

If we examine soaked peas, pumpkin seeds, cucumber seeds, flax seeds, apple seeds, peach seeds, etc., we shall find that they have parts corresponding to the parts of the bean. All of these plants and many more have two seed leaves. All of our forest trees except the evergreens produce seeds with two seed leaves.

**231. Grain.**—Corn, wheat, oats, rye, and a few others are called grains and are quite different in structure from the bean. Since corn grains are largest, it is easier to see the parts in them. Soak some corn for about twenty-four hours or in warm water for a few hours and then find the parts that correspond to the parts of the bean. The leathery covering can be removed, but not so easily as from the bean. The hollow or sunken side of the grain contains the seed leaf, and in the middle of this leaf we find the tiny corn plant. The end of this plant toward the cob end of the grain is the root and the other end forms the top, when it grows. We see that the seed leaf, and there is only one, and the young plant form but a small part of the entire grain. The larger part of the grain contains food for the little plant, and the seed leaf also has some food in it.

**232. How to Test Seeds and Grains for Nutrients.**—Take a little corn starch and mix it with water, add a drop or two of a weak solution of iodine and observe the color. Now put a few drops of the iodine solution on soaked beans and corn and see if the color shown by

the starch appears; if so, then beans and corn contain starch. Split some corn grains both ways and see which part of the corn is mostly starch.

To test for protein, take some white of an egg or bread, which we already know contain protein, and put on it some strong nitric acid and observe the yellow color; then add a few drops of ammonia and notice the yellow color change to orange. Save a sample of the yellow and orange colors for comparison with other tests. Now put strong nitric acid on some beans and corn, giving it several minutes to act; observe the color and then add some ammonia. Do corn and beans contain protein?

By holding a corn grain to the light we can see a small section on either side through which light seems to pass; this part contains oil or fat.

**233. Germination.**—When the young plant in a seed or grain starts to grow, we call that germination. In order to make sure that we learn how it takes place, it will be best to plant seeds of various kinds. Plant them about one inch deep in moist soil, sand, or sawdust, or between moist blotting paper; remove one or two each day and examine them carefully to see how they are growing and which parts are growing. Plant some beans, peas, pumpkin seeds, corn, and wheat, and note carefully the difference in the way they come out of the soil. What is the difference between the growth of beans and peas? Between pumpkins and beans? Between corn and beans? Does the root or the top start from the seed first? Why?

All kinds of seeds and grains contain digestive ferments called *enzymes*. An enzyme in grains is called *diastase*. Diastase is a chemical ferment which changes starch to sugar without itself being changed. When the plant starts to grow more diastase is produced from the grain. Plants

can use only soluble foods, and since starch is but very slightly soluble, it is changed to sugar — which is easily soluble — for the use of the plant.

The conditions necessary for these enzymes to act are also the conditions necessary for rapid germination. What is the temperature of the air in the room where plants are growing? What is the temperature of the air outside when seeds are planted? By experimenting we shall find that a temperature near 75° F., or 24° C., is favorable for the germination of seeds. A moderate amount of moisture, or enough to keep the seeds damp, is best. The seeds of the most useful plants will not germinate if they are covered with water or if the soil is kept too wet. The reason for this is that germinating seeds need air, and they cannot get sufficient air while covered with water. Place some beans and corn in water for several days and see if they will grow. The conditions necessary for germination are a moderate temperature, a moderate amount of moisture, and air or oxygen, as they use only the oxygen of the air. We can easily prove that light is not necessary for germination by giving some seeds the three necessary conditions and then wrapping them in black paper to exclude the light.

**234. Roots.**— We recall that we saw in beans and corn the part of the young plant which during germination becomes the first true root of the plant, and that we observed that the root grows first during germination. The root grows into the soil to get water and soluble food for the stem and top of the plant. Roots take water and food from the soil before all the food in the seed or grain is consumed. The way in which roots take up soil water is an interesting process and to learn how it is done we shall have to perform some simple experiments.

If we place some mustard, radish, or turnip seeds between moist blotting paper and keep the paper moist for two or three days, we shall find that the roots of the germinating seeds are covered with tiny white threads, standing straight out from the root, and some of them about an eighth of an inch long. These white threads are called root hairs, and they take up most of the moisture for the growing plant. Root hairs are composed of only one cell, and the soil water flows into them and thence into the main root. All new roots are covered with these root hairs. When large trees start to grow in the spring, they first grow very small new roots at the ends of the old ones and these new roots are covered with root hairs which absorb the soil water for the trees.

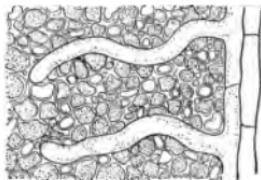
These root hairs are composed of *protoplasm* and are filled with sap which is more dense than ordinary soil

water; the soil water passes through the thin wall of the root hair and then into the larger root. This process by which a liquid flows through an animal or plant membrane is called *osmosis*, and the greater flow is toward the denser liquid. The pressure caused by osmosis in the roots is sufficient to lift the sap many feet.

If no osmosis apparatus is at hand, the effect of osmosis can be shown in the following way: Fasten a glass tube to the narrow end of an egg with paraffin or sealing wax; then with a long wire carefully puncture the shell of the egg inside of the glass tube so that the contents of the egg can flow up the tube.



ROOT HAIRS  
ON A YOUNG  
ROOT



ROOT HAIRS IN THE SOIL

Also showing air spaces.  
Magnified.

Carefully remove some of the outer shell from the larger end of the egg, but do not injure the tough membrane just inside the shell or the contents of the egg will flow out. Now fasten the egg so that the larger end is in water and the glass tube standing vertically. After a few hours the white of the egg will be forced up the tube by the water flowing through the membrane at the bottom, the greater flow being toward the denser liquid.

The general direction of roots is downward; but, like the tops of plants, they send out branches which grow sideways and sometimes just beneath the surface of the soil. These branch roots send out other branches which may grow either up or down or sideways. They will not grow up out of the soil, but they grow close to the surface where they can get abundant dissolved food. Many roots of corn run horizontally close to the surface. There are three things which determine or influence the direction in which roots grow: (1) Force of gravity tends to cause roots to grow downward. (2) Roots grow most rapidly where there is abundant food, because they receive more nourishment. (3) Water influences the direction of growth. If the soil is dry, the deeper roots will grow because they have a food supply. If the soil is excessively wet, the surface roots will grow, and the deeper roots will turn upward or to a horizontal position to keep out of the water; for this reason the soil should be well drained to permit the roots to go deeper and thus have a larger feeding area and also sufficient water when a dry season comes. If the roots are all near the surface, plants suffer for want of water during a dry season.

**235. Stem.**—Recall the part of the young plant in the seeds and grains which, during germination, grew and formed the stem or the part of a plant above the ground.

We also observed that the general direction of growth of the stem is upward, opposite to that of the first roots. The stem takes a vertical position, that is, vertical to the horizontal plane. The trees on a hillside do not stand perpendicular to the slope, but perpendicular to the horizontal plane of the earth. The branches from the main stem grow outward as do root branches. The roots grow outward to get food, while the branches from the stems grow outward to get light.

If we examine the structure of a cornstalk and a limb of a tree, we notice a marked difference. The cornstalk has a hard rind and a large pith with hard, stiff fibers running through it. There is no true bark like that on a tree or like that on flax. The microscope shows that these threads in the pith and also in the rind of the cornstalk are full of holes running lengthwise, through which the sap flows.

The cross-section of the limb of a tree contains a very small pith in the center and a true bark on the outer edge and hard wood between the pith and bark. We can see distinct rings in the woody part; these are the annual rings and the space between any two rings is the wood that grew during one summer. There are also lines or rays running out from the center to the bark, much like the spokes of a wheel. These lines all extend to the bark, but they do not all extend to the pith because a few of the rays are started in each annual ring and are continued after they are once started. These rays serve as storehouses for food and for the flow of sap across the tree.

If we examine with a magnifying glass the smoothly



SPLIT STEM OF  
A TREE

*p*, pith; *h*,  
hard wood; *s*,  
sap wood; *b*,  
bark.

cut end of a tree limb or the end of a piece of board, we shall find it full of very small holes. The soil water taken in by the root hairs passes up through these holes. These holes or tubes are not usually more than a few inches long. The ends are separated from one another by a very thin partition or membrane through which the sap passes by osmosis. By osmosis the sap continues to pass from tube to tube until it reaches the leaves at the ends of the limbs or the top of the tree. By examining the cross-section of a large tree like the oak, we find a white ring an inch or more in thickness just inside the bark. This white wood is living and is called sap wood; most of the sap flows up through this living part. The brown wood inside the white ring is dead and is useful for food storage and to support the tree. This brown part is most valuable for lumber because it does not decay so quickly as the sap wood. All first-class lumber has the sap wood removed.

The bark of a tree is dead on the outside and is continually falling off; much of it may be pulled or cut from many kinds of trees without injury to the tree. The dead part of the bark on a young tree or twig is very thin and should not be removed. This outer bark serves to protect the tree from insects and diseases. The inner part of the bark next to the sap wood is living and is called *cambium*, or the cambium layer. This cambium layer forms bark on its outer side and new wood on the inner side next to the sap wood. It makes this wood and bark out of the digested food which flows down from the leaves through the cambium and the bark next to it.

The outer bark of some trees is very useful to man. The bark of oaks and of hemlock is used for tanning

leather. The cork-oak has a very thick outer bark which is somewhat spongy but water-proof and is valuable for corks for bottles. It is taken from the trees in large sheets and the corks are often cut perpendicular to the flat surface.

**236. Leaves.**—We again recall that beans, squash seeds, peas, etc., have two seed leaves, and that there are two very small leaves visible on the young plant in the beans. These two little leaves become the first true leaves of the bean after it germinates. We have noticed that all the plants which we have grown formed leaves as soon as they came through the soil. This being true, we conclude that leaves are useful and necessary to plants. To determine whether they are useful, from day to day pick leaves from a few young plants, and see how it affects their growth.

Gather a dozen or more leaves of various plants and compare them to see in what respects they are the same. Do they all have a stem? This stem is called the *petiole*. The broad body of the leaf is called the *blade*. In the blade there are lines or ridges called *veins*. The sap flows through these veins. When these veins branch and run in all directions, the leaf is said to be netted-veined. Oak, bean, maple, etc. have leaves that are netted-veined. When the veins all run in the same direction the leaf is parallel-veined. Corn and many grasses have parallel-veined leaves. In general, seeds that have two seed leaves produce plants with netted-veined leaves and grains with one seed leaf produce plants with parallel-veined leaves.

Most leaves are covered with very fine hairs or a whitish, woolly substance, usually more on the under surface than on top. This extra covering helps to keep water out of

the leaf during a wet season or during rain; it may also help to keep out disease bacteria and parasitic plants. If we dip a green leaf in water, we can see that a thin layer of air is held on the leaf by this extra covering, and when the leaf is removed from the water, the water does not adhere to the surface of the leaf.

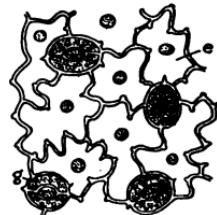


SECTION OF A LEAF

*e*, epidermis; *c*, cells containing chlorophyll bodies; *p*, intercellular passages; *g,g*, guard cells. of stoma. Magnified.

The blade of the leaf has a thin layer of cells forming the upper and lower covering or skin of the leaf; this layer is called the *epidermis*. Just under the upper epidermis is a layer of long cells with their ends against the epidermis and arranged in column form; hence the layer which they form is called the *palisade* layer. Between this palisade layer

and the lower epidermis is a layer of loosely arranged cells with large air spaces between them; this layer is the *spongy tissue*. The air in these air spaces in the spongy tissue can pass in and out through very small openings, which are in the lower epidermis of most leaves. These openings in the lower epidermis are called *stomata* (plural of *stoma*). There may be many thousand stomata to each square inch of surface. The air passes in and out of the stomata by filtration. There are two almost semicircular cells around each stoma, which can easily be seen with a microscope; they are called *guard cells*. By changing their shape they control the amount of air that can pass through and also control the amount of evaporation of water from the leaf.



LOWER SURFACE OF LEAF

*e*, ordinary epidermal cell; *g*, guard cell. Magnified.

The roots of a plant take up soil water by osmosis and it flows up through the stem, through the petiole of the leaf, and through the veins into the palisade layer. The air is composed of about .04 per cent of carbon dioxide ( $\text{CO}_2$ ). This carbon dioxide passes through the stomata into the leaf, where it and the soil water are used as the raw materials for the manufacture of starch. The energy necessary for this manufacturing process comes from the sun in the form of heat and light. Rapid starch making by leaves requires a moderate temperature and abundant sunlight. Each cell of the leaf between the lower and upper epidermis is full of green-colored bodies called *chlorophyll* bodies. These give the green color to the entire leaf. The chlorophyll bodies are formed in the leaf when it is exposed to sunlight. When a leaf is shaded, the chlorophyll disappears and the leaf turns white or yellow. This can be seen by lifting a board that has lain for some time on grass, by growing some plants in the dark, or by noticing the yellow leaves on the under part of a tree that produces a dense shade.

These chlorophyll bodies in the presence of sunlight make starch by combining water ( $\text{H}_2\text{O}$ ) with carbon dioxide ( $\text{CO}_2$ ):  $6\text{CO}_2 + 5\text{H}_2\text{O} = \text{C}_6\text{H}_{10}\text{O}_5 + 12\text{O}$ .

This starch, made during the day, must be changed to sugar, a soluble substance, before it can be moved from the leaf down the stem of the plant, where it is stored in the form of starch (the sugar having been changed back to starch), or it is joined with other elements in the soil water and then used for growth, or it is stored in ripening fruits in the form of protein, or the sugar may be changed to fat or oils and stored in the fruit. Name some fruits or seeds that contain starch, or proteins, or oils. What commercial oils come from fruits or seeds?

We now see why plants and trees should be thinned out sufficiently to permit them to get air and sunlight. Plants that are crowding one another cannot be healthy and productive. Fruit trees that are not properly pruned and thinned have so many branches that they cannot all get sunlight and sufficient air, and so the lower and inner fruit-spurs or branches die and what little fruit is grown is of inferior quality. Fruits like peaches and apples are covered with openings for the inward and outward passage of gases, and for this reason they need sunlight and air or they will not grow properly and will not be colored. Even small twigs are covered with openings for the passage of gases; these openings can be seen with the unaided eye and are called *lenticels*.

Man and other animals are dependent upon the leaves of plants for their food either directly or indirectly. Hence man must learn how to care for the plants that he wishes to cultivate in order to make them productive.

**237. Flowers.**—When a seed germinates, it first grows a root, then stem, leaves, and finally at a comparatively mature stage flowers appear. The flower is grown for the purpose of producing new plants. To find how this is done it is necessary to make a close study of complete flowers. Examine some flowers of fruit trees, or wild flowers from the woods, or some in the home, and find all the parts. We shall see that some flowers contain parts which are not necessary for reproduction and some which are necessary for reproduction; the former we call non-essential parts and the latter essential parts.

The non-essential parts consist of the *calyx* and *corolla*. The calyx is the outer whorl of leaf-like parts of the flower and is often green in color. One of the divisions of the calyx is called a *sepal*. The corolla is the second

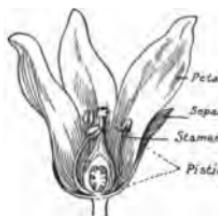
whorl of leaf-like parts just inside the calyx. The parts of the corolla are called *petals* and they are usually colored.

These parts which are non-essential for reproduction are the parts which give beauty to blossoms and which make flowers so attractive for decorative purposes, and also give them their high commercial value. Florists aim to grow principally those plants which produce beautiful sepals and petals; so from the standpoint of the florist the non-essential parts are very desirable.

The essential parts consist of *stamens* and *pistil*. The stamens are usually within the corolla, and each stamen is composed of (1) a thread-like part called the *filament*, (2) the *anther*, which is often a knob-like body on the outer end of the filament, and (3) the *pollen*, which is usually a yellow, powdery substance that grows in the anther. The pollen dust is composed of two-celled bodies of various shapes, which may be plainly seen when viewed through a microscope. The stamens are the male parts of a flower.

The pistil is in the center of a flower and is composed of three parts. The base of it is called the *ovary*, which is usually the largest part of the pistil and contains little bodies called *ovules*; these can often be seen with the unaided eye. On top of the ovary is a slender stem called the *style*, and at the end of the style is the *stigma*. The pistil is the female part of the flower.

For fruit to be produced, the pollen from the anthers must get on the stigma. It does this in several ways. The anthers may burst when they are ripe and throw



PARTS OF A SIMPLE FLOWER

the pollen on the stigma; this is *self-pollination*. Bees and other insects may carry the pollen from one flower to the stigma of another flower of the same kind; this is *cross-pollination*. The wind may blow the pollen about and some may fall on the proper stigmas. Corn is pollinated by the wind.

The stigmas are covered with a sweet, sticky substance which prevents the pollen from falling off and also causes the pollen grains to start to grow or germinate much like seed, but they only form a growth corresponding to the first root of a germinating seed. The pollen grain forms a root-like tube without branches, which grows down through the stigma and style and into the ovary. In the ovary are ovules, each one of which contains an embryo sac, and in this sac is an egg cell which cannot grow unless it is fertilized by the sperm cell of a pollen grain. This sperm cell of the pollen grain goes down the pollen tube, and when the pollen tube enters an ovule in the ovary, the sperm cell joins with the egg cell to form a cell known as a fertilized egg. Each pollen grain can fertilize only one egg cell, so each pistil needs as many pollen grains on its stigma as there are ovules in the ovary; each ovule has one egg cell. In order to provide for this, some plants grow many thousands of pollen grains for each ovule in the ovary. In the case of flowers that are pollinated by the wind or by insects, much of the pollen goes to waste and never falls on a stigma.

After the egg cell is fertilized, it immediately starts to grow and form a young plant with root and top like that in a bean or in a grain of corn. This is an *embryo* plant or immature plant. While the embryo plant is being formed, the parent plant stores food around it. When

the embryo is of sufficient size and the proper amount of food is stored, the ovary is mature and the fruit is ripe. A fruit is a ripened ovary.

Fruits and seeds are scattered by the wind, water, animals, and by the fruit pods bursting open and throwing out the seeds. Fruits are grown for the purpose of starting new plants away from the parent plants and also to carry plants over unfavorable climatic changes like cold weather during winter. Man makes conditions favorable for plants to grow so that they will produce large quantities of fruit for food. Make a list of plants grown for their fruit; keep in mind that a fruit is a ripened ovary.

**238. Production of New Varieties.**—In the previous section we learned that some flowers are self-fertilized and that most of them are cross-fertilized in order to produce seeds which in turn produce new plants. When the pollen from a flower of one plant falls on the stigma of a similar plant, a seed is grown which when planted will produce a plant that is more or less different from either of the two parent plants. This difference may not be noticeable or it may be very great. If seed is always selected from plants which show a difference from the parent plants, new varieties may gradually be produced. This selection may take place among wild plants and thus produce new varieties, but man with his intelligence is always selecting the best seed from the most productive plants with the result that the farm crops per acre have greatly increased and many new and productive varieties have been produced. Luther Burbank of California has produced wonderful results simply by selecting the plants that show an improvement and letting them grow to produce seed for the next crop. Most

farmers can still greatly improve most of the plants which they grow by selecting seed from plants which show an improvement caused by cross-fertilization.

Sometimes cross-fertilization produces a plant that is very different from the parent plants. When these far different plants can be made to reproduce themselves, a new variety comes into existence. New varieties of corn, wheat, etc. have been produced in this way.

**239. Seedless Fruits.**—There are many so-called seedless fruits, such as navel oranges, lemons, bananas, and pineapples. The method by which these are produced is largely one of selection and by means of budding. Seedless oranges, lemons, grapes, and bananas bloom like other fruit trees. In the navel oranges the embryo sac, which normally would develop into embryos and be fertilized by the pollen, disintegrates before fertilization takes place; hence they do not form seeds, but the fruit develops as usual except that it is lacking in seeds. Occasionally a few embryo sacs develop normally, and in the event that these particular embryo sacs happen to become fertilized by the pollen of a similar variety, there will be seeds in fruit which is ordinarily seedless. For this reason seeds are occasionally found in navel oranges.

When a tree produces nearly all seedless oranges or lemons, it is propagated by budding or grafting, that is, a bud from the seedless orange tree is cut off and fixed into the bark of a young orange tree in such a way that it grows and forms a tree that produces seedless fruit like the one from which the bud was taken. In case of grafting, a twig is taken instead of a bud. In this way many trees are soon grown from which buds for budding can be selected from the trees that produce the most seedless fruits. The young orange trees which are budded

are grown by planting healthy seeds from fruits with seeds.

In the case of the banana, however, the disintegration of the embryo sacs has become such a fixed habit that seeds are never found in cultivated varieties. Pineapple plants are propagated by cuttings, and only very rarely can a seed be found in a pineapple. These cuttings are shoots or "suckers" which spring up from the base of the old plants. These new cuttings bear fruit after from fourteen to eighteen months. A pineapple plant grown from seed does not grow fruit until after it is ten or twelve years old.

#### QUESTIONS AND EXERCISES

1. What is the difference between beans and corn on the bases of appearance and structure?
2. What nutrients do beans and cereal grains contain? Why are such plants grown?
3. Explain the process of germination of seeds.
4. What are the necessary conditions for the growth of healthy plants from seeds?
5. In what direction do roots grow? Why? Of what use are roots to plants?
6. What are the conditions for osmosis to take place? Does osmosis occur in your body?
7. Does the root or stem grow first from a germinating seed? What are the parts of the stem of a plant? Give the use of each part.
8. What are the parts of a leaf? Give the use of each part.
9. Is it better for trees to have the leaves fall off every year? Explain.
10. Why do plants grow flowers? Name the parts of a flower. Give the use of each part.
11. How are new varieties of plants produced?
12. How are seedless oranges grown?

## CHAPTER XXXV

### HOW PLANTS ARE PROPAGATED

**240. By Use of Seeds.** — Seeds contain an embryo plant with sufficient food stored with it to support it till roots, stem, and leaves are formed. The ground must be properly prepared so that the roots can get food from the soil before all the stored food of the seed is consumed.

Corn in northern United States is usually planted in May, in rows 42 inches apart and from one to one and one-half inches deep in the soil. Winter wheat is sown in September and October, in rows eight inches apart and about one inch deep. Small seeds like clover and many garden seeds are sown on the surface. The surface of the prepared soil in the garden is usually stirred just enough to cover the fine seeds. Raindrops cause clover seed to settle into the soil enough to become covered.

**241. By Use of Roots.** — Many cultivated plants are propagated by keeping the roots over the winter in a place where they will not freeze and then planting them in the spring. Examples are dahlias and bulbs of tulips and hyacinths. In the North sweet potatoes are planted in hotbeds and young plants grow from the old roots. These plants when about six inches high are transplanted about 10 inches apart in rows which are from two to three feet apart. In the South the sweet potatoes are cut into small pieces and planted like the white potatoes in the North.

Many garden plants are propagated by both roots and seeds. The seed of onions is often sown so thick that only small onions grow the first season. These small onions are called onion sets, and are kept over the winter and planted the next season to produce big onions. Cabbages and turnips store food the first year in the head and roots respectively, and will grow seed the second year if replanted.

Many wild plants reproduce by seeds and roots also.

Nearly all of the early spring flowers have rootstocks and bulbs in which food is stored for early growth. The May

apple spreads by growing underground a root which has a bud on the end to make a plant above ground the next season. Many grasses reproduce by sending out stem-like rootstocks just beneath the surface of the soil. Blue grass is an example.

#### **242. By Use of Cuttings.—**

The white or Irish potato is a tuber and an enlarged underground stem. The eyes are buds which will grow when conditions

are favorable. For planting, the potatoes are cut into pieces with two or more eyes on each piece. One or two of these eyes may grow and produce potato stalks



SHOWING PROPAGATION OF WHITE CLOVER BY RUNNING STEM



GRAPE CUTTING AND THE SAME AFTER ONE YEAR'S GROWTH

which in turn grow new tubers. The white potato grows wild in South America.

Many plants can be grown by cutting a branch and placing a few inches of the larger end in the ground. The branch or limb must have buds on it. The part which is in the soil will grow roots and that part above the soil will grow stem and leaves. Examples are the poplar, willow, currant bushes, and grapevines. The grape should be cut with three buds on the part to be planted,

two buds to be covered with soil and the third one left above the soil.

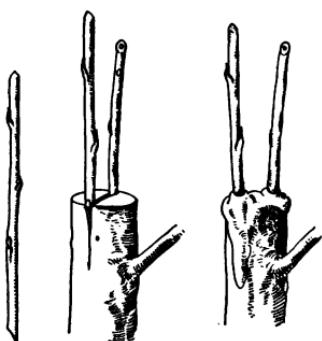
#### **243. Grafting and Budding.**

—Grafting and Budding are forms of propagation by cuttings and are used for the purpose of growing fruit of the same variety as that from which the grafting twig or bud was taken. Since fruits with pulp,

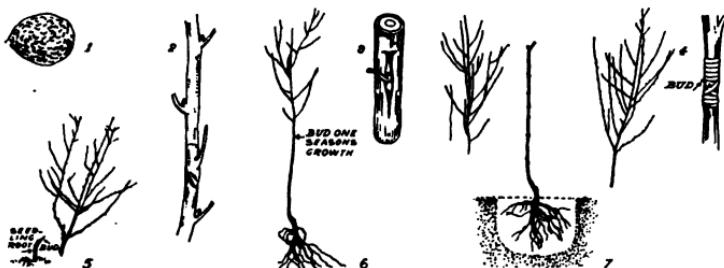
GRAFTING A TOP BRANCH

like apples and peaches, are mostly cross-fertilized in the blossom, the seeds, if planted, will not produce trees that will grow fruit just like the parent trees.

The most important thing to be known about grafting and budding is that the cambium layer of the bark of the two parts must touch in such a way that the sap can flow from one to the other. For grafting, the wedge-shaped cut is very convenient for bringing the cambium layer of each part into contact. Twigs about six inches long may be cut and tapered off in the form of a wedge at the end opposite the terminal bud. The grafting twigs are called *scions*. For top-grafting the end of a small limb or the top of a young tree is cut off and a wedge-split



made. If the limb is larger than the scions, two scions may be fixed in position so that the cambium layers touch properly, and then covered with grafting wax and wrapped. When very young trees are grafted, scions of the same diameter as the tree are used. For root grafting, small



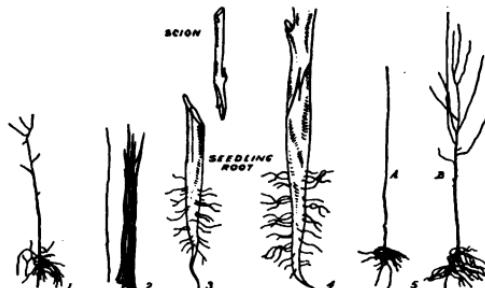
#### PROPAGATION OF PEACH TREES

1. Peach seed selected for planting.
2. Bud stick, taken from the tree of the variety wanted, grown on seedling root.
3. Peach bud in position.
4. Peach seedlings, one season's growth, with bud placed in position, which was done in August during growth of seedling.
5. Peach seedling with top cut off above the bud, in the spring of the year following after the bud has been placed in position; only the bud has been allowed to grow.
6. Peach tree dug, showing bud top and seedling root six months after top of seedling has been cut off.
7. Peach tree showing both seedling roots and bud, trimmed ready to plant in orchard or permanent place.

roots from eight to twelve inches long are cut and scions of the same diameter are placed at the proper ends, or seedling roots may be used. Root grafting is now used very extensively for propagating fruit trees of known variety and quality.

For budding, buds instead of scions are cut from desirable trees, and these buds are set in proper cuts made in very young trees. Usually a T-shaped cut is made in the bark at the base of the young tree and the bark loosened

sufficiently so that the bud can be put in position. After the bud starts to grow the top of the tree is cut off just above the bud. Since there is a large system of roots made by one season's growth in the soil, the new bud will



#### PROPAGATION OF APPLE TREES

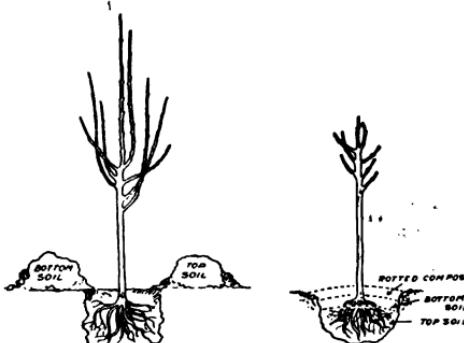
1. Seedling one year old, grown from seed trees propagated on seedlings. The process of budding apple, pear, plum, and cherry is the same as the peach except that seedling, instead of seed, is planted in nursery rows and the bud is usually grown two years instead of one.
2. Apple scions for grafting on seedling roots. Scions are taken off when trees are dormant in the fall.
3. Splice of tongue or whip graft.
4. Graft and root united. Bark of scions and root should make perfect union. Grafting is usually done by a nurseryman in January and February and placed in storage for spring planting.
5. *A.* One year old apple from graft, showing growth of both top and roots. *B.* Two year old apple from graft, showing two years growth of top and roots.

be well supplied with food, hence it will grow rapidly. Budding is used by fruit growers more extensively than grafting.

**244. Transplanting** — Many plants can be grown on a very small area while they are young or mere

seedlings, and can be cared for with less labor and expense than if the seeds were planted over an area required for mature growth. Seeds of cabbage and tomato and lettuce are often sown in hot beds and when the seedlings are from four to six inches high, they are transplanted where each plant will have room for mature growth.

All kinds of fruit trees are grown by planting the seeds a few inches apart in rows which are about three feet apart, which permits proper cultivation while the trees are young. The second year the trees are either budded or grafted and then they are allowed to grow from one to three years before they are transplanted on areas



SHOWING HOW TO TRANSPLANT AND PRUNE YOUNG TREES

large enough for them to grow to maturity and bear fruit. Most fruit growers now plant trees which have tops only one year old, so that they can start the limbs of the trees high or low as they wish. Trees can be transplanted in the late autumn after the leaves have fallen, or in the early spring before the buds start to grow.

For transplanting fruit trees or shade trees successfully the following suggestions may be followed:

- (a) For trees with a top one year old: With a sharp knife cut all branch roots back to about one inch from the main or primary root.
- (b) For older trees leave the branch roots longer, but

be sure that all broken, cracked, or bruised roots are cut off back of the injury. A smooth cut will heal more quickly than a break.

(c) Cut the top back in the same proportion that the roots have been cut. A transplanted tree with a large top and few roots will die.

(d) Dig the hole about two feet square and 15 to 20 inches deep. Place the top soil on one side and the sub-soil on the other side of the hole.

(e) Plant the trees about one inch deeper than they were before; the color of the bark will show how deep they were in the soil. Put the top soil into the bottom of the hole and around the roots and tamp it solid with your feet or hands. Fill the hole with the sub-soil and tamp again. Apply water if the soil is dry.

(f) If planting where there is sod, save the sod to be replaced; but leave several inches of space between the sod and the tree.

**245. Shade Trees.**—Shade trees around country homes and on the streets of cities serve many useful purposes. They add beauty, shield the houses from winds, and in summer give protection from the sun's heat and also serve as homes for birds; on these accounts shade trees add value to property.

Those trees should be planted which are easily grown,



LARGE SUGAR MAPLE IN A FIELD

which are free from attacks of diseases and insects, and which produce the least amount of objectionable waste matter (such as the woolly substance on the leaves of the sycamore or buttonwood). A tree on which the leaves come out early and hang till late autumn is also desirable. The particular locality will determine which trees possess these characteristics.

Trees which send their roots into sewers, cisterns, and wells should not be planted, for they will always cause trouble. The poplar, willow, and buttonwood are of this type.

**246. Forest Trees.** — The American people have been too wasteful and careless in cutting trees and are now beginning to realize the loss thus incurred. The lumbermen are being advised as to the best methods of caring for the young trees. The waste limbs are being thrown into heaps to prevent the spread of destructive forest fires. Young trees are often planted where old trees are cut down, so that the forest is renewed. Many paper mills own the forests from which the soft wood is obtained for making paper and they have the wood cut at the season when the most new sprouts will grow from the stumps of the trees. Then in 10 to 20 years they can cut over the same ground again. Soft wood grows rapidly.

The United States Department of Forestry has control of thousands of acres of forest land and trained men, called forest rangers, travel about in these forests to indicate what trees ought to be cut and to care for the young trees and also to prevent forest fires.

Every farmer or large landowner ought to have all waste land covered with trees, if possible. Where there is no waste land or land unfit for cultivation, at least 10 per cent of the farm should be growing trees. Pasture

lands should have trees somewhere for the protection of the stock during unfavorable weather.

#### QUESTIONS AND EXERCISES

1. At what time of the year are the various crops planted in your community?
2. Which crops are grown from seeds? Which from roots? Which from stems?
3. Cut some scions and graft them on a tree of the same kind.  
(Grafting is usually done in the spring before the leaves come out.)
4. What is the purpose of grafting and budding?
5. What vegetables and trees are transplanted?
6. What kinds of trees are best for shade? How should they be planted?
7. Are there sufficient trees in your community? Are they properly cared for?

## CHAPTER XXXVI

### USE OF PLANTS TO MAN

**247. Plants for Food.** — Primitive man or man in the savage condition gathered much of his food from wild plants, using the roots of some and the fruits of others, such as nuts and berries. Later he learned to care for



HARVESTING WHEAT IN WASHINGTON

these food-producing plants and also learned to cultivate productive grasses from which wheat, rye, oats, and rice were developed. The latter are natives of Asia and have been cultivated by man for several thousand years. Corn originated from a grass which is a native of Mexico. The

American Indians cultivated corn with their crude implements. It is now the largest food crop in the world and more corn can be grown per acre than of any other grain.

Potatoes are natives of South America. They were cultivated by the Indians and were not used by white people until after the discovery of America. Now they form a large part of man's food.



HARVESTING SUGAR CANE IN HAWAII

Most of our large fruits are natives of Europe and Asia. With modern conveniences of transportation and refrigeration it is possible for people in temperate climates to get tropical fruits in large quantity, making oranges and bananas as cheap as apples. Pineapple culture is increasing rapidly and this fruit is now less expensive.

Modern methods of canning make it possible to preserve perishable vegetables and fruits. In cans, they can be transported as needed and will not spoil if they are kept at medium temperatures.

**248. Plants for Clothing.** — Man even in the wild or savage state must have food in order to live, but in warm climates he can do without clothing and so he wears but very little. As he progresses in civilization he increases his clothing until his whole body is covered. Most of the primitive clothing was made of skins and furs of animals,



TRANSPLANTING RICE IN JAPAN

but man in the civilized condition has learned to use many kinds of plants for clothing. Some of these plants are cultivated and some grow wild.

Cotton a few years ago was cultivated exclusively for its fine fiber which was and is used for making clothing. Cotton needs a long season for its growth and so it is raised only in warm climates. In the southern United States it is usually planted in March and harvested in September and October. The seeds are covered with a

long white fiber which is removed from the seed by a machine called a cotton gin. The fiber is used for making thread, yarns, and clothing. The oil is pressed from the seeds and is known as cottonseed oil. It is used for making artificial butter, and as a substitute for olive oil, which it resembles.



PICKING COTTON IN ARKANSAS

**Flax** is grown in temperate climates. The northern United States and Europe produce large quantities. It requires a great deal of labor to care for it properly. Just before the seed is ripe the flax stalks are pulled up, roots and all, and kept moist during a period of "retting," after which the inner part of the stem and the outer bark are removed from the sieve cells or inner bark. This inner bark fiber is combed into very fine threads, out of which linen thread and clothing are made. The white linens

have been put through a long bleaching process and do not wear as long as the cream-colored, unbleached linens.

Flax is also grown for its seed from which an oil is extracted and used for making paint. This oil is known on the market as "linseed oil." The inner bark of the flax cannot be used to make linen after the seed is ripe.



HARVESTING FLAX IN SOUTH DAKOTA

Hemp and sea grass are used for making rough garments and also for making summer hats and rugs. The straw of wheat is used extensively for making hats. The cellulose or wood fiber of trees is used for making artificial silk. The cellulose is dissolved and then forced through very fine holes; this process makes a fine, lustrous fiber that can be made into clothing.

Jute is an East Indian plant used for making mats, rugs, etc.

**249. Plants for Ropes and Twines.** — The common cord used in stores is made of cotton fiber. The heavy brown

twines are made of flax, hemp, and jute. The parts unfit for clothing are made into twines. A large quantity of small rope, the size of wash lines, is made of cotton. Binder twine and large, heavy ropes are made of hard fiber like that obtained from manila hemp and sisal. Large ropes are made by twisting together several smaller ropes or twines.

**250. Plants for Paper.** — The earliest records were cut on stones; these were very hard to handle and also easily broken. Later, records were made on prepared skins of animals; this method is still used — examples are college diplomas. Still later, the fiber of the papyrus plant which grows in Egypt was split into sheets and records made on it.

After printing was invented it became necessary to have paper in large amounts. Parchment made of skins of animals was expensive and not sufficient in quantity, so paper was made of rags (not of woolen rags) and of straw. But as the great printing presses came into use these sources of paper supply were not sufficient. Now forest trees are cut, ground into small chips, and acted on by hot chemicals; the wood fiber, *cellulose*, is then thoroughly washed and rolled into large sheets of paper. The paper of this book is made of wood. Only soft wood, like the poplar and spruce, is used for paper making.

The best paper is made of linen or flax fiber. Cotton and wood make a paper of medium quality. Straw makes very poor paper. All kinds of rags, other than woolen, and waste paper are gathered, baled, and sent to paper mills to be worked over and made into new paper.

**251.** The following table will give some idea of the quantity of plants produced in the United States during the year 1913.

Product	Total Acres	Production per Acre bu.	Total Yield Bushels	Price per Bushel
Corn.....	105,820,000	23.1	2,446,980,000	69.1 cents
Wheat.....	50,184,000	15.2	763,380,000	79.9 "
Oats.....	38,399,000	29.2	1,121,768,000	39.2 "
Barley.....	7,499,000	23.8	178,189,000	53.7 "
Rye.....	2,557,000	16.2	41,381,000	63.4 "
Buckwheat....	805,000	17.2	13,833,000	75.5 "
Potatoes.....	3,668,000	90.4	331,525,000	68.7 "

**ANIMALS REPORTED FOR 1914**

Milk cows....	20,737,000	Value per head	\$53.94
Other cattle ..	35,855,000	" " "	31.13
Swine.....	58,933,000	.....	.....
Sheep.....	49,719,000	.....	.....
Horses.....	20,962,000	.....	.....

Silk exported from Japan during the year 1912..... 23,413,000 pounds

**QUESTIONS AND EXERCISES**

1. What is the historical origin of the principal plants used for food?
2. What commercial products are made of wheat, rye, oats, cotton, potatoes, and flax?
3. Examine various kinds of rope and determine the kind of material of which each is made.
4. Make a list of the plants of which paper is made. Which ones have you seen?

## CHAPTER XXXVII

### LOW FORMS OF PLANT LIFE

**252.** The earth is covered with life, much of which to the average observer consists of trees, shrubs, weeds, grasses, and cultivated (useful) plants. But these plants which are most visible are not the most numerous. The plants with green leaves are able to take food from the soil and air and to make the three nutrients which are used for growth and which are also stored in the seeds; such plants are considered to be high in the scale of development or evolution and they serve as food and clothing for man.

Plants which do not have distinguishable leaves, stem, and roots, we consider low in the scale of development. Many of these low forms of plant life are very useful and necessary for other plants and for man; while many of them are harmful to both higher plants and animals. Some of them are useful in one place and harmful in another; the same can also be said of trees and grasses.

These low plant forms are divided into two groups, namely, *Algæ* and *Fungi*.

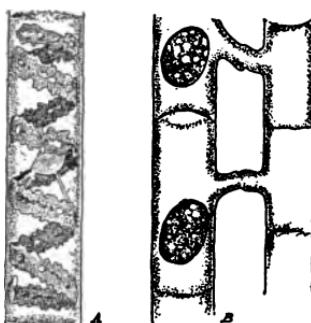
**253. Algæ.** — *Algæ* have chlorophyll and are able to make starch of water and carbon dioxide, thus preparing their own food. The *algæ* vary in size from the simple microscopic form to the largest plant in the world. The giant kelp of the Pacific Ocean attains a length of over 1,000 feet; it is an alga. The brown-colored rockweed

along the coast is an alga. Some fresh-water algae are the pond scums, which can be found on the water in swamps and ponds. Some simple, one-celled algae can be found on rocks and on the bark of trees. They give to the rock and bark a greenish color.

One pond scum is known as *Spirogyra*, so-called because of its spiral appearance under the microscope. It can be found floating on the surface of the water in masses composed of hair-like threads with bubbles of gas distributed through it. This gas, composed mostly of oxygen, causes the *Spirogyra* to float. It grows by using the impurities in the water and the carbon dioxide of the air. When starch is being made, there is an excess of oxygen gas which is given off and forms the bubbles which hold the plant on the surface where it can get more sunlight and air. This plant is useful in so far as it lives on the impurities in the water and gives off oxygen to the air. It is harmful to the extent that it gets into drinking water and gives it a peculiar odor and taste.

A thread of *Spirogyra* is made up of a single row of cells attached end to end. A thread increases in length by the cells dividing — one cell becoming two cells, the ends remaining fixed to each other.

*Spirogyra* does not bloom and grow seed like the higher plants, but, when a time that is unfavorable for growth comes, it produces a cell that corresponds to a seed. This cell is known as a *spore*, sometimes called *zygospore*. It



SPIROGYRA — A POND SCUM

*A* is one cell; *B* is two spore cells formed by the union of two other cells.

is formed by the contents of two cells flowing together to make one strong cell. This new cell can withstand extreme temperatures and also dry weather. The wind may carry it about as dust, and when it falls into a pond it will start to grow and form a new plant if the temperature is right. These spore cells are usually formed by the union of the cells of two threads lying side by side.

**254. Fungi.** — The fungi form a very large group of plants that do not have green coloring matter or chlorophyll, and so cannot make starch of water and carbon dioxide. Their color is mostly white, and they live on the juices of other plants which are living or dead. Those fungi which take their food from living plants are called *parasites*, and are generally harmful. Those which live on decaying matter are called *saprophytes*, and most of them are useful except when they grow where they are not wanted. The common fungi are mushrooms, molds, and yeast.

There are about 400 kinds of edible mushrooms which grow wild in the woods and fields. Some are grown under cultivation. The part of the mushroom which is eaten is only the spore-bearing part. The roots of the mushroom are in the ground or in decaying matter on which they grow. One mushroom top may produce millions of spores (seed-like organs) which are scattered by the wind.

The molds are useful in decomposing dead matter so that it can be used again by higher plants. Molds are harmful when they decompose useful dead matter such as lumber and foods. One common kind is the black mold which grows on bread. To grow some, take a piece of old bread, moisten it, and roll it on the floor to gather some dust containing the mold spores, and then put it away for two or three days, being sure to keep it moist.

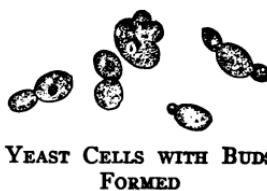
The mold spores on the bread will germinate and send their root-like threads into the bread to absorb the food. In a day or two these threads in the bread will be large enough to send up above the surface some threads with black knobs on the end. Each knob is full of ripe spores waiting to be carried away by the air.

Yeasts are fungi, and there are many kinds of them. They are harmful when they grow on fruits and in fruit juices which we want to keep for some time. They are useful for producing carbon dioxide to raise bread, and for fermenting grains and other substances for the production of commercial alcohol.

To see yeast plants with the microscope: Mix a small piece of soft commercial yeast in a little water containing a small amount of sugar, let it stand an hour or so, and then take a drop of the liquid and place it on the microscope slide. The oval-shaped bodies are yeast.

**255. Bacteria** compose a group of fungi of about 1,000 kinds, of which about 20 are parasitic to man and cause disease; the others are useful or harmless. These parasitic bacteria can live on man because of improper methods of living on the part of most people. Man's uncleanness and over-indulgence are largely responsible for the existence of parasitic bacteria which produce disease.

Bacteria are useful in causing the decay of useless dead matter, which can then be used by growing plants. They are absolutely essential in the soil to produce foods for various plants. Most plants have to have their particular kind of bacteria in the soil or they cannot grow. Bacteria are also useful in preparing certain foods. Cheese and butter are examples.



YEAST CELLS WITH BUDS  
FORMED

Food which we want to keep for some time must be protected from bacteria or they will cause it to decay. This is done by heating the food and then sealing it, or by using a preservative in which bacteria cannot grow. Many of these preservatives are harmful to man as well as to the bacteria, and should not be used.

#### QUESTIONS AND EXERCISES

1. Examine old stone fences and the bark of large trees to see if they are covered with some greenish substance. The green material consists of a one-celled alga called pleurococcus.
2. Visit a pond or swamp and examine some pond scum. In what way is it useful?
3. What use is made of mushrooms, mold, and yeast?
4. Explain in what way certain bacteria are more useful than harmful.

## CHAPTER XXXVIII

### PLANT DISEASES AND PESTS

**256.** The low forms of plant life are useful for decomposing dead plants and animals, but when they become parasites on living plants and animals then they are harmful. Many fungi and bacteria have become true parasites and live on the higher plants cultivated by man. The plant on which a parasite lives is called the host. The most destructive parasitic plants are rusts, smuts, mildews, and blight-producing fungi and bacteria. These parasites attack cultivated grains, fruits, and vegetables, and the damage done by them annually amounts to hundreds of millions of dollars.

**257. Wheat Rust.** — Wheat rust is considered one of the most destructive parasitic fungi. It passes part of its life on the barberry and part on the wheat. It extracts its food from the leaf of the wheat, which is soon killed, so that no grain is produced. Damp, warm weather is favorable for its growth, and a crop of wheat may be killed in a week. About the only remedy is to remove the barberry. Other wheat rusts, not so destructive, live entirely upon wheat. The remedy for these is not to sow wheat on the same ground many years in succession.

**258. Apple Rust.** — The life history of the apple rust or cedar rust is given in detail, in order to show how to kill or control it, and also to serve as a type in understanding the nature of a double host parasite.

This parasitic fungus attacks both the apple and the cedar. On the cedar it produces brown, corky galls or knots, called cedar apples or cedar flowers. These galls are comparatively slow in developing, and a cedar tree which becomes infected in July or August of one year does not show any noticeable effects until May or June of the following year. At this time the young galls may be noted as small green or greenish-brown enlargements, and they do not complete their development until the next spring, when they produce spores to infect the apple.



CEDAR APPLE

Which produces spores  
that cause apple rust.

The spores which the cedar apples finally produce are only about one-thousandth of an inch long and a little less in width. They serve to propagate the fungus in much the same way as seeds reproduce the higher plants. These spores, like seeds, will germinate and grow if they

find favorable conditions. They require the young, growing leaves of certain varieties of apples as a place in which to grow, and they must receive moisture within a comparatively short time or they will dry up and die. The spores germinate in from three to five hours by sending out a germ-tube which penetrates the tender leaf just as an ordinary plant root would go into the soil, and when it once gets into the leaf, it cannot be killed by spraying. This thread-like growth absorbs its nourishment from the apple leaf, and the plant food which should be used in fruit formation or tree growth is used by the fungus. The tiny threads slowly work their way around in the leaf tissue, but do not produce a visible spot for about

ten days. Such spots soon assume a characteristic yellow color and become slightly swollen on both the upper and lower surfaces. These leaf spots mature rapidly, and within about two months they send out clusters of cylindrical fruiting bodies on the under surface of the leaf. The fungous spores which are borne in these fruiting bodies are not able to grow on apple foliage, but they are carried to the cedar trees and again produce the cedar apples.

The damage done by apple rust is very extensive. In some cases entire crops of York Imperial apples are lost. Some varieties are injured more than others. The remedy is to remove all red cedars from which the wind can blow the spores to the orchard, and to spray the apple trees with lime-sulphur solution, 1-40, about five to seven times in five weeks, beginning when the blossom buds show bright colors. Bordeaux mixture is almost as good as lime sulphur.

**259. Brown Rot.** — Brown rot is a fungous disease which attacks stone fruits, being most destructive on plums and peaches. It also attacks apples and pears. The chief symptom of this disease is the appearance of a brown-colored rot in the fruit. It may appear while the fruit is still green or on ripened fruit. Sometimes it makes its appearance after the picked fruit has been sent to market. It causes ripened fruit to decay very rapidly. As the disease progresses on green fruit, tiny, gray, spore masses break through the skin and the wind scatters spores by the thousand to other fruit. The rotted green fruit soon shrivels and dies, and may fall to the ground or hang on the trees. The dried fruit on the trees, known



BROWN ROT  
The mummies  
that carry the  
disease through  
the winter.

as mummies, under the influence of the warm spring rains, develops masses of new spores, which when carried by the breeze to blossoms and green fruit start the rot anew. The mummies which fall to the ground and become only about half-covered produce spores which cause blight of the blossoms.

*Remedy.* — Gather all mummies from the trees and ground and either burn them or bury them more than six inches deep. Spray dormant trees with lime-sulphur solution, 1-8, to kill spores adhering to the limbs. Self-boiled lime-sulphur spray will help to protect peaches in the summer. Remove all fruit noticeably affected to prevent the development of new spores.

**260. Pear Blight.** — Pear blight is a disease caused by bacteria. It is also called fire blight. It sometimes attacks rapidly growing apple and plum trees. It is easily recognized by the sudden death of blossoms and ends of growing twigs. The attacked leaves turn black and cling to the twigs after the other leaves have fallen. Sometimes the disease runs down the limbs and kills the whole tree. Dead spots or cankers are formed on the limbs and bodies of trees at the base of blighted spurs and watersprouts. At times the fruit is affected and dries on the tree.

The bacterium lives over the winter in the cankers. In the spring, sticky, milky drops, containing many bacteria, run out from these hold-over cankers. Insects of various kinds carry the bacteria from the cankers to the flowers and tips of growing twigs. The feet of the insects make very slight wounds into which the bacteria can pass, and then the bacteria multiply rapidly, causing the blight to become visible in from ten to fourteen days.

*Remedy.* — The diseased limbs and twigs should be removed as soon as discovered, always cutting several inches below the noticeable affection to be sure to remove all bacteria. Always disinfect the cut surfaces and also the cutting instrument after each cut. The cankers in which the bacteria live through the winter can be cut off with a sharp knife. Cut well back into the healthy bark, scrape out the diseased parts thoroughly, and sponge the wound with corrosive sublimate solution, one part to 1,000 parts of water. After the wound is dry, keep it painted with good lead paint until the wound is healed over.

**261. Other Diseases of Plants.** — There are many other diseases caused by parasitic plants. Bacteria produce the diseases known as blight of beans, cucumber wilt, soft rot of turnips, black rot of cabbage, crown gall of peaches, pears, and apples.

Additional diseases caused by fungi are apple scab, which passes the winter on fallen leaves; potato scab, which is largely propagated by being planted with the potato; and blight of potatoes.

Apple scab attacks the leaves and young apples about blossoming time. Spraying just before blossoming and just after will largely control the scab.

Potato scab lives over the winter on the potatoes and also in the soil in which the potatoes grew. It can be

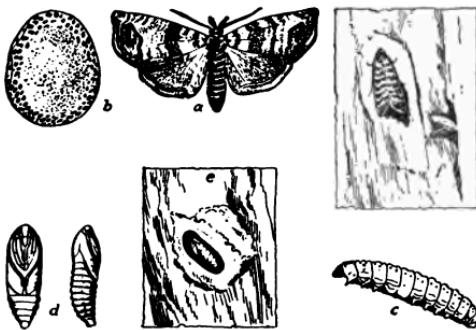


SAN JOSÉ SCALE  
Natural size on the left; much enlarged on the right.

controlled by treating the "seed" potatoes with formalin solution before planting, and by rotation of crops.

Potato blight attacks the leaves of the potatoes and causes them to die. It can be prevented by keeping the potatoes covered with Bordeaux mixture to prevent the entrance of the fungus spores. About five sprayings

are necessary, but one or two more are sometimes given.



STAGES OF THE CODLING MOTH

(a) the moth or adult insect, slightly enlarged; (b) the egg, greatly enlarged; (c) the full-grown larva, slightly enlarged; (d) the pupa, slightly enlarged; (e) the pupa in its cocoon on the inner surface of a piece of bark, reduced about one-half; (f) moth on bark and empty pupa skin from which it emerged, about natural size.

### 262. Insect Pests.

—The animal pests which injure cultivated plants are mostly insects. The San José scale, which is a sucking insect, reproduces very rapidly and is very destructive to both peach and apple trees. It can be killed by spray-

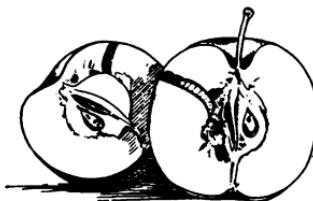
ing with strong lime-sulphur solution when the leaves are off of the trees. Spray that is strong enough to kill the scale will also kill the leaves.

The codling moth, a small insect, is very destructive to apples and pears. The adult moth deposits its eggs on the young apple just after blossoming. The egg hatches and the larva crawls to the blossom end of the apple and eats its way into it. The apples thus attacked usually fall when they are about the size of thimbles. About this same time the worm or larva reaches its growth and

emerges from the apple to find a favorable place to go into the pupa stage. During the pupa stage, wings and other adult parts of its body are developed. It comes out an



APPLES RIGHT FOR  
SPRAYING  
To kill the codling moth.



CODLING MOTH LARVA  
And its work.

adult in time to produce a second generation in the apples that escaped the first attack.

*Remedy* — Spray apple trees with a poison such as arsenate of lead just as the petals are falling from the blossoms, forcing the spray well into the blossom end of the apple. Spray again about the middle of the summer, if necessary, when the second generation of the moth appears.

#### QUESTIONS AND EXERCISES

1. When is a plant a parasite? Name some parasites. What is the plant called on which parasites grow?
2. Examine the under side of some growing leaves for a yellow substance. What is it?
3. Give the life history of the apple rust. Examine some green apple leaves and cedar trees to determine the various stages of the apple rust. How can it be destroyed?
4. Examine peach, plum, and cherry tree sfor brown rot. What remedy can be used?

5. During the summer watch pear trees for dead twigs caused by pear blight. What is the best remedy?
6. Examine trees for various kinds of scale insects. Which is the most destructive?
7. Winter apples sometimes contain "worms." What is the name of the "worm"? How did it get there? What is the best method of destroying this insect?

## CHAPTER XXXIX

### THE ANIMAL SERIES

**263.** We have already learned from our study of plants that they vary in size and structure from the one-celled bacteria to the many-celled giant trees of the forest. Animals also vary in number of cells and complexity of structure from the one-celled microscopic animals to the largest and most complex type. This chapter gives a general view of the animal life of the world by studying the animals in groups arranged approximately according to their complexity. All animals can be divided into two groups — the one-celled animals and the many-celled animals. The many-celled animals can be divided into a great many subdivisions, such as worms, insects, crustacea, fish, amphibia, reptiles, birds, and mammals.

**264. Protozoa or One-celled Animals.** — There are many one-celled animals which can be found in stagnant water such as that found in swamps or ponds. There are two one-celled animals which can be easily found and of which we shall here make a careful study. The simpler of these two is the *amœba*. It is a mass of protoplasm, somewhat granular in structure, which has no definite form or shape and moves about by putting out projections, and when it encounters any food, such as bacteria, it rolls itself about them and thus takes the bacteria within its own protoplasmic body. It absorbs the food value of the bacteria and discards the waste matter chiefly through the part of its body called the contractile *vacuole*.

Its method of reproduction is mostly by simple division. As it absorbs food it increases in size until it reaches the stage at which it divides into two equal parts, forming two new *amœbae*. These two new amœbae eat and grow in



THE WAY AN AMOEBA GETS ITS FOOD

like manner as the parent until they reach maturity, when they divide the same as the parent amoeba. After the amoeba has divided from fifty to one hundred times, a complex process takes place during which there is a revitalization of the animal in order to increase its capacity for reproduction by simple division. This complex process is thought to be a sexual process. There are several stages through which the amoeba passes, and it is thought that in some of these stages it is able to live as a parasite on higher animals, causing disease. The

amoeba has no particular value to man except that it devours a great many bacteria which may be harmful.

The second one-celled animal which can easily be found is the *paramecium*.

It can be grown in what is known as a hay infusion. Place a small handful of ordinary hay in a jar and cover it with water. In a few days bacteria will cause the hay to decompose, the water will change color, and



PARAMECIA

the bacteria will collect on the top of the water in a mass, making a scum. The few paramecia that were on the hay will regain active life and start to eat the bacteria collected on the top of the water. If a drop of this scum is placed on a glass slide and observed with a microscope, a great many one-celled animals, granular in structure, will be seen moving about very rapidly in the microscopic field; these are paramecia. They are able to move by lashing the fine hair-like projections of the protoplasm of their bodies. These hair-like projections are called *cilia* and are not ordinarily visible under the microscope.

The paramecia, like the amoeba, reproduce by simple division, forming two new animals. The two young paramecia grow to maturity after feeding for some time, and then divide again. After a number of generations have been produced, two paramecia of about equal size join together and exchange a part of their nucleus protoplasm. This exchange of nucleus protoplasm increases their vitality so that they are able to increase more rapidly by simple division. This exchange of nucleus protoplasm is thought to be a sexual process.

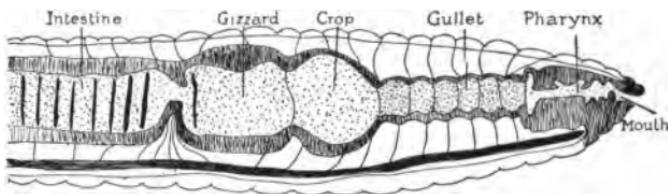
The paramecium is somewhat more complex than the amoeba, although it is a one-celled animal. It has a special place through which to take in food, called its mouth. It also has special organs of locomotion, called cilia, and the part of its body used for throwing off waste matter is called the contractile *vacuole*.

Its value to man is of very slight importance. Its only known uses are to dispose of bacteria which collect on stagnant water and to serve as food for fish and tadpoles.

Of the other one-celled animals there are some which are

very useful to man but very difficult to obtain. Some of these have lived in such great numbers that the skeleton-like forms of their bodies have formed great deposits in various parts of the world. The most widely used of these deposits is chalk, of which crayon for writing on the blackboard is made. There are great deposits of chalk in the central and southern United States and also in England. Another one-celled animal forms deposits of quartz-like material.

**265. Worms.** — The worm which is most easily found and studied is the common earthworm. It lives in the



FOOD TUBE OF AN EARTHWORM AND THE RINGS OR SEGMENTS  
INTO WHICH ITS BODY IS DIVIDED

soil but is found in greater abundance where the soil is fertile. It burrows into the earth by making holes and swallowing the earth as it goes. It is able to move by two actions of its muscles. It has a layer of muscles running lengthwise of its body, which shorten the worm when they contract. Another layer of muscles runs around its body and lengthens the worm when they contract. It also has projections on the lower part of its body which can be directed forward or backward and prevent the worm from sliding except in the direction in which it wants to go. The worm is covered with a slimy, mucus-like secretion which keeps its body moist, and on account of this moisture it is able to take oxygen from the air; this

is a form of breathing. During heavy showers, when the worms' holes in the soil become filled with water, the worms come out to the surface because they cannot get sufficient oxygen while covered with water. For this reason great numbers can be found on the streets and sidewalks or on the surface of lawns and parks after a heavy rain. The worm has no definite part of its body for seeing, yet it is sensitive to light and also sensitive to touch.

The economic value of the earthworm to the farmer is very great. The holes which it makes in the soil give opportunity for soil ventilation or aeration. It also carries large quantities of earth to the surface and thus keeps the soil in continuous circulation or movement, making it more fertile. The food of the earthworm is mostly the root hairs of growing plants or any other organic matter in the soil which it swallows while burrowing.

There are also a great number of other worms, such as sandworms. These can be found along the seacoast and sometimes along rivers and lakes. There are also a great number of worms which are parasites to man. These will be studied later.

**266. Insects.** — Of all the animals now living, the insect is probably the most completely fitted for its environment, and on this account it is winning its way in the struggle for life. An insect usually has six legs and three divisions of its body. The three divisions are known as the head, the thorax, and the abdomen. The legs are all attached to the thorax or the middle division. Most insects have two pairs of wings. Those which have only one pair of wings prominent have two rudimentary wings called "balancers." These can easily be found on the common housefly.

The life history of an insect is very interesting for observation and study. There are four principal stages through which the insect passes. First, the egg stage; second, the larva stage or eating period; third, the pupa stage; fourth, the adult stage. During the pupa stage the insect changes its body from the worm-like form to that of the adult. In the adult stage the insect has six legs, usually two pairs of wings, and some have a proboscis for eating liquid foods, while some do not eat at all

in the adult stage. The insects which do not eat during the adult stage live only a week or so. Flies, mosquitoes, and some butterflies which eat liquid foods may live for months or even over the winter in the adult stage.

**267. Crayfish.** — Crayfish are very common and can be found in creeks and in holes in the ground, ranging from low swampy ground to the hilltops. Their principal use to man is as scavengers, that is, they devour quantities of decaying animal matter in the creeks or about the holes which they make in the ground.

The body of the crayfish is covered with a bony-like shell, an exoskeleton, which serves to protect it from its enemies. It can swim backward very rapidly by swift motions of its tail, which is composed of several flat bony-like parts. It has two stalked compound eyes which enable it to see in all directions, and it is thus able to escape its enemies. It has five pairs of legs, all of which are attached to the thorax. The four back pairs are used



A CRAYFISH

mostly for locomotion, while the front pair, which are very much enlarged at their extremity, are used for grasping and cutting food and also for carrying the food to the mouth. It has two long projecting antennæ which serve as feelers and also for smelling. It moves forward slowly while in search of food, but in case of danger it moves backward swiftly—a motion caused by rapid, forward jerks of its tail—and seeks protection under stones or other objects in the water, or in the bottom of its hole if it happens to be a land crayfish. It reproduces by depositing eggs, which are carried about on the under side of the body until hatched. The young crayfish which come from the eggs also attach themselves to little projections, called swimmerets, on the under side of the body of the parent, until they are able to find food and care for themselves.



A CRAYFISH MOVING BACKWARD

The thorax of the crayfish is a bone-like armor which extends from the back around to the bottom of its body, but the lower edge is not grown to the body of the crayfish. Just under this bony covering are feather-like projections called gills. The blood flows through these gills and takes oxygen from the air in the water. The crayfish causes a current of water to flow over these gills in order to keep a fresh supply of oxygen going into its blood and carbon dioxide coming out.

The North American lobster is a close relative of the crayfish. It grows in the salt water along the Atlantic coast in great numbers and is a valuable source of food. Various states have different laws regulating the size

of the lobster which may be sold in the markets. The state of Maine forbids the sale of a lobster less than four and one-half inches from the rear of the thorax to the end of the bony projection between the eyes, making the entire lobster about ten and one-half inches in length. They are caught chiefly by means of traps 4 feet long and 18 inches in diameter, flat on the bottom and semi-circular on the top. A net incloses each end of the trap and in the net there is a hole large enough for the lobsters to walk through. Once they are on the inside they are unable to find their way out. Dead fish are used for bait and are placed in the center of the trap. The traps rest on the bottom of the ocean, usually in water from 10 to 50 fathoms in depth. A rope extends from the trap at the bottom to a float on the surface of the water so that the fishermen can find the rope and draw up the trap containing the lobsters.

The lobster, like the crayfish, molts very often during the earlier part of its life. After becoming eight inches or more in length it molts once a year. During the molting season the North American lobster moves near the shore, where it has more protection under the rocks and is less liable to be attacked by fish which prey upon it during this season.

**268. Amphibians.** — An amphibian is an animal which lives part of its life in water as a fish does and part on land, breathing by means of lungs. It also has an internal skeleton instead of an external skeleton as the crayfish and insects have. Two common examples of amphibians are frogs and toads. In the spring they deposit their eggs, which are inclosed within a gelatin-like substance in order to protect them from fish which might eat them. The eggs hatch in a very short time and after the young,

called tadpoles, are large enough to take care of themselves when they emerge from this gelatin-like substance.

The tadpoles breathe with gills the same as fish, and their means of locomotion are nearly the same as those of fish. The tadpoles live by eating very small animals and plants found in the water. The difference between a frog tadpole and a toad tadpole is that the frog tadpole is grey in color and has a longer body with a heavier tail than the toad tadpole, which has a short, round body and a very slender tail, and is black in color. The frog tadpole also requires the whole summer and sometimes a part of two summers to grow to maturity, while the toad tadpole grows to maturity in about one half of a summer.



THE DEVELOPMENT OF A FROG

1, eggs; 2, tadpole; 3, tadpole developing hind legs; 4, same tadpole but larger; 5, front legs appearing; 6, tail being absorbed; 7, frog in adult form.

When the tadpoles reach what may be called the mature stage, the gills are lost and lungs are developed within the body; legs also appear, the hind ones first, and the tail is absorbed into the body, the material being used for the building up of the legs. After the frog or toad has changed into the form of the adult with lungs and four legs, it spends most of its life on land. Frogs spend much of their time sitting on the bank watching for insects. In the winter

they hide in the water and breathe through their skin; since their activity is slight they do not require much oxygen. The toads hide away in holes in the ground during the winter and are in an almost lifeless condition.

The idea that it rains toads came into existence because the toad tadpoles can change from the tadpole stage to the adult form in about 24 hours. If a rainy season or heavy shower occurs just at the time when they are changing from the tadpole to the adult stage, the roads or fields about ponds, where the tadpoles are numerous, are alive with young toads — hence many persons concluded that the toads were rained.

**269. Economic Value of Amphibians.** — Frogs serve as food for man; they also devour great numbers of insects which would be harmful to plants that man grows. Toads, since they travel over land away from the water, are of much greater value than frogs in destroying insects. Several toads in a garden will keep it almost clear of the harmful insects which prey upon valuable plants.

**270. Reptiles.** — Common examples of reptiles are snakes, turtles, and alligators. They have an internal skeleton and a scaly covering; the turtles in addition have a bony covering. Reptiles are close relatives of birds. They reproduce by eggs which have a tough covering and contain considerable food for the young while in the process of incubation. Snakes usually deposit their eggs in holes made in the ground; tortoises do the same. Some snakes are poisonous, such as the rattlers, copperheads, and blowing vipers. The rattlesnake makes a noise with its rattles when it is disturbed, to give warning before it attempts to bite. An additional rattle is added each year after the third year. Copperheads give no warning whatever, but conceal themselves in order to wait

for the opportunity to bite. Blowing vipers make a hissing noise as a warning to an approaching enemy.

The economic value of reptiles is not very great. Snakes devour a great many bugs, some insects, and many field mice, which are harmful to the crops. Turtles serve as food for man. The skin of alligators is used for making various useful leather articles.

**271. Birds.** — The relation of birds to reptiles can be observed by noticing the scales on their feet and by comparing their eggs with the eggs of reptiles. The principal difference between the eggs of birds and those of reptiles is that birds' eggs have a hard, limy shell on the outside and a tough membrane inside, while the eggs of reptiles have only a tough but flexible membrane for a covering. Some fossil remains of birds have also been found which give evidence that birds originated from reptiles.

Some birds are more destructive than beneficial; for instance, the English sparrow, the crow, and the blackbird. The English sparrow was introduced into the United States in 1850, at Brooklyn, N. Y., in order to destroy the insect known as the cankerworm, but it soon changed its habit of living upon insects to that of living upon grain and seeds, and thus became a menace to the welfare of the insect-eating birds instead of being an insect-destroying bird itself. It is able to adapt itself to all the conditions of its environment. It does not migrate, but during the winter finds shelter in and around buildings. In the spring the English sparrow builds its nest, which is very large; the inside is lined with soft feathers; and in it four to six eggs are deposited. The female incubates the eggs until hatched and then the parent birds start to feed the young. Immediately the female again deposits eggs in the nest with the young sparrows, which now incubate the

eggs instead of this being done by the female sparrow. If a nest is torn down in the middle of the summer, you will find in it eggs and birds of various ages up to those that are mature and ready to fly out. This method of reproduction makes the English sparrow very prolific and it becomes a menace to the welfare of all other birds. Many states offer a bounty of two cents a head for English sparrows in order to bring about their destruction.

The crow, a large black bird, migrates, going south in autumn and coming back in the spring. Crows are very destructive to germinating corn in the farmers' fields in the spring. Their diet consists mostly of grain, but occasionally they take up the habit of hawks, eating small birds and even young poultry grown by the farmers. They also rob the nests of other birds. They gather in great flocks during their migrating season and stop occasionally on the migrating tours in the various grain fields to gather their evening meals.

The blackbird is about half the size of the crow. They also migrate, traveling in great flocks, living largely upon the farmers' productions. About two-thirds of their diet, however, is composed of insects and bugs of various kinds.

The birds most valuable to the American farmer are the robin, bluebird, martin, and various other kinds of songbirds. Their principal value is in destroying or consuming great numbers of insects which are harmful to the crops.

The domesticated birds which can be found on any farm originated from various types of wild birds. The chickens have originated from a wild bird of Asia and the geese and ducks from various types of the wild kind. Many of the birds which have given origin to domesticated

birds are the game birds which are still in existence in the wild state. Some of these are the wild geese, ducks, and turkeys. The quail, a game bird, does not migrate, but adapts itself to its surroundings the whole year round, living upon whatever it is able to find, eating some grain but mostly wild berries, seeds of wild plants, and insects. Wild geese and ducks migrate from north to south with the change of seasons. They fly in flocks, usually in the form of a V, the leader of the flock is at the apex of the V.

**272. Mammals.** — Mammals compose a group of animals which are the most highly developed of all. The egg produced by the female is microscopic in size and is fertilized within the body of the mother, and there grows into the young animal with all the parts of an adult. After birth the young are nourished for a time by milk secreted by the mammary glands of the mother. Examples of mammals are the elephant, lion, mink, cat, dog, horse, cow, monkey, and man. A number of the mammals are plant-eating or live entirely on plants. Some of the animals which live upon plants serve as food for those which live upon flesh. Those animals which live on other animals acquired the habit of eating flesh because it was more easy to get sufficient food by that method than to gather their nourishment from plants. Some of the flesh-eating animals are those of the cat family. There are some animals which eat both plants and flesh. The domesticated dog and cat have acquired the habit of eating both plant and animal food. The bear also lives upon plant and animal food. The opossum, a native animal of North America, lives upon both plant and animal food.

Nearly all of the domesticated animals which man now possesses originated from animals of like kind living in

the wild state. The dog is supposed to have originated from the wild dog, and the cow from various wild types; a near relative of the cow is the buffalo. Wild cats are still in existence in various parts of the Appalachian Mountains. Elephants have been domesticated and are very valuable beasts of burden. The horse is a native of North America. It originated from an animal about the size of a wolf. It had four toes on each front foot and three toes on the hind feet. It gradually acquired the habit of walking on the middle toe of each foot. This caused the bones and hoof of the middle toe to enlarge and the other toes to decrease in size, so that now they cannot be seen except occasionally on some horses when an extra hoof appears. The horses which developed the bones of the front toe were more swift than those which did not, because they had longer legs and thus were able to escape their enemies and keep their kind in existence. The horse finally migrated to the Asiatic continent where it was first domesticated by man, and since that time it has been greatly improved and many types have been produced, varying in size from a pony of a few hundred pounds to the huge draft horse weighing one ton.

All other domesticated animals which are of economic value have also been greatly improved by the study of biology, which has enabled the farmers to control the types and kinds which they wish to maintain. Cattle have been produced which weigh 2,000 pounds, and some have been produced which are immune from various kinds of diseases. The hog — the pork-producing animal — has also been greatly improved, so that it grows to weigh several hundred pounds in less than a year; some have been produced which weigh from 600 to 800 pounds after two or three years of special feeding.

**QUESTIONS AND EXERCISES**

1. To grow some one-celled animals, place some hay, green grass, or lettuce in water and let it stand at room temperature for a few days. A scum will appear on the surface of the water. This scum is composed of bacteria and one-celled animals. Place a drop of the scum on a microscopic slide and examine.
2. Dig some earth worms and observe their means of locomotion and their habits. What do they eat?
3. Examine carefully some house flies, mosquitoes, or other insects and learn their parts and habits.
4. Look in creeks, ponds, or swamps for crayfish. Of what use are they to man?
5. Gather some eggs of toads or frogs and watch them develop into animals. Of what value to man are frogs and toads?
6. In what way are birds and reptiles similar? How are they different? How are birds of more value to man than reptiles?
7. How has man changed the size and shape of domesticated mammals? Of what value are wild mammals?

## CHAPTER XL

### ANIMALS AS DISEASE CARRIERS

**273.** Many bacteria and one-celled animals have become parasitic in their habits and live in the bodies of the higher animals, producing a condition known as disease. Most of these diseases can now be cured, but a few still resist medical science and are very dangerous. In order for man to protect himself from germ diseases it is necessary for him to know how germs are carried about from place to place. Some germs are carried on the outside of the bodies of animals and some are carried on the inside. Those which are carried on the inside of animals have a complicated life history. Part of their life is spent in the animal and the other part in man. There are also some many-celled animal parasites which spend part of their life in domesticated mammals and the other part of their life in man. These parasitic diseases are obtained by eating the flesh of domesticated animals.

**274. The House Fly.** — The house fly is also known as the typhoid fly because it carries the germ which produces typhoid fever. The typhoid fly, in going about in various places in search of food and of places for depositing its eggs, comes in contact with a great deal of filth and decaying matter; here it often gets the typhoid germ on some part of its body, usually its feet. It then goes into the house and may walk over the food which man eats or the utensils from which he eats, leaving the typhoid germ

to be taken into man's body with the food. The only use that the house fly serves is that of a scavenger, helping to decompose decaying organic matter. If the body of a fly is viewed under the microscope, it will be seen to be well fitted for carrying germs. Its legs and feet are covered with hairs; and its head and proboscis are also very rough. It has two compound eyes which enable it to see in all directions, making escape from its enemies easy.

The life history of a house fly should be known in order that we may be able to destroy it most effectively. It deposits its eggs in garbage cans or in decaying matter about barns and other outbuildings or even in decaying logs in the woods. In a day or so the eggs hatch and the larva eats the material in which it lives. The larva has no legs, but can move slowly by twisting and bending its body. It is white in color, and in about



MAGNIFIED  
Foot of a  
House Fly  
Showing  
how it is adap-  
ted for carry-  
ing germs.

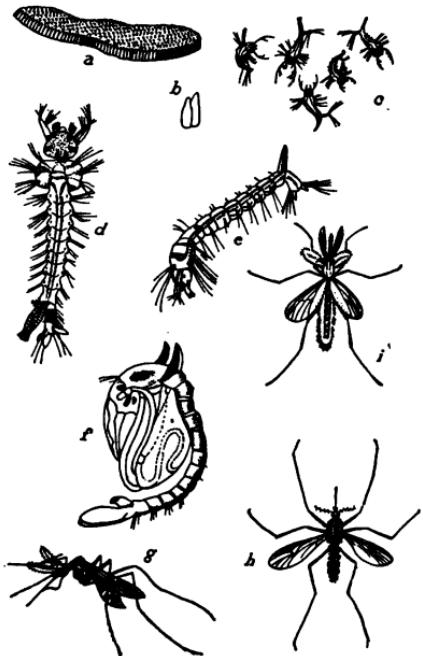


LIFE HISTORY OF THE HOUSE FLY  
(a) Adult. (b) Eggs. (c) The larva or grub stage. (d) The pupa.

five to seven days grows to maturity, when it is about a half inch in length. When the larva stops eating, a brown coating is formed over its body and it is then in the pupa stage. It does not take any food while in this condition, but the six legs and

the wings, head, and eyes are developed. It takes from five to seven days for it to change from the pupa to the adult state. At the end of the pupa stage the fly comes out a full grown adult. Flies vary in size, but this variation

is due to the quantity of food eaten during the growing period. After the fly has been in the adult stage for two or three days, eggs are again deposited, making a complete generation in from 12 to 16 days. It is possible to have as many as eight or ten generations of flies in one summer.



LIFE HISTORY OF THE Mosquito

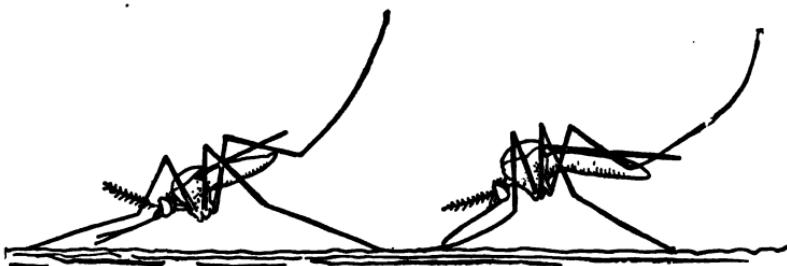
- (a) Raft of eggs. (b) Eggs enlarged.
- (c) Larvæ or wrigglers. (d) and (e) are larvæ enlarged. (f) Pupa; (g) and (h) are females. (i) is a male.

The house fly can easily be destroyed by removing or covering all places where it is in the habit of depositing eggs, thus preventing their production. It can also be destroyed in the adult stage by poisons and traps and various other means which man has devised for the purpose.

**275. Mosquitoes.** — The life history of the mosquito is similar to that of many other insects. Their eggs are laid on water and in a day or so they hatch and the larvæ emerge. The larvæ feed upon

bacteria in the water, and in a few days they change from the larva stage to the pupa stage. The larvæ are commonly known as wrigglers and hang under the surface of the water with their heads downward, breathing through a tube in their posterior end, which they extend just above the surface of the water. If

the water is covered with oil, the larvæ are unable to breathe through this tube and so they die. When the larvæ change to the pupa stage they still remain under the surface of the water, breathing through a tube, but they do not eat. In the pupa stage, wings and legs and other necessary organs for the activities which they perform during the adult period are developed. The adult mosquito flies about and lives as a parasite upon other living animals by forcing its proboscis into the skin of the animal and extracting blood. This



MOSQUITOES IN RESTING POSITION

On the left the malarial mosquito (*Anopheles*); on the right the harmless mosquito (*Culex*) (From Howard's *Mosquitoes*).

habit of obtaining food makes it possible for the mosquito to carry a disease from one person to another. If the *Anopheles* mosquito secures a meal of blood from a person who has malaria fever, it will take some of the germs into its body; these will pass into the stomach, thence into the blood of the mosquito, and into its salivary glands, and then when it bites or secures a meal from a person who does not have malaria fever, some of these germs are forced out from its salivary glands, thus conveying the germs to a healthy person, who then becomes a subject of the disease. The mosquito known as the *Culex* does not carry any disease. The *Culex* lays its eggs in rafts, usually

two rows side by side, the eggs standing on end, while the *Anopheles* lays its eggs singly and not in groups. The body of the adult *Culex* is in a horizontal position when at rest, while the body of the *Anopheles* is almost vertical when at rest. The yellow fever mosquito, or the *Stegomyia*, carries the yellow fever germ much the same as the *Anopheles* carries the malaria germ. It secures a meal from a person who has the yellow fever. It takes the yellow fever germ into its body and is then able to transmit those germs into the bodies of persons who do not have the disease. Yellow fever used to be very common in our Southern states and in the Panama Canal zone; but the destruction of the mosquito in these regions has almost eliminated the disease. There are three methods which are used for the destruction of the mosquito. (1) Keep the water in swamps and streams covered with oil so that the larvæ cannot breathe. (2) Drain the swamps wherever possible so that the mosquito cannot find a favorable place for depositing its eggs. (3) Keep the water stocked with fish which eat the larvæ of the mosquitoes.

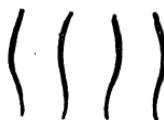
**276. The Rat and Flea.** — The rat is a native of China and has moved westward over the Asiatic and European continents. It came to the United States in 1775, and in 75 years worked its way across North America to San Francisco. It was definitely learned in 1907 that the rat carries a very destructive disease. This disease almost depopulated many cities in Europe during the past centuries; the cause of the disease was not known at that time. Many superstitious people thought that it was a plague visited upon the people by God for their sins. The disease is known as the Bubonic plague or Black Death, and about 95 per cent of those who

contract it die. The germ does not seem to have any injurious effect upon the health of the rat. The flea, which is an external parasite of the rat, will carry the Black Death germ from the rat to man when it takes a meal from the rat and then an occasional one from man. This was proved in 1907, when 150,000 rats were dissected in San Francisco. In order to rid the city of San Francisco of the Bubonic plague and also of the rat, hundreds of thousands of dollars were spent. Ten million pieces of poison were laid, and it is supposed that more than two million rats were killed and washed out into San Francisco Bay. It is considered by some that the enemy Black Death, which was gaining entrance into the United States through San Francisco, was more dangerous than the combined army and navy of the most powerful nation of the world. In Havana, in 1914, twenty city squares were depopulated and the rats driven out in order to eradicate the germs of the Bubonic plague. In order for man to be secure from the Bubonic plague it will be necessary for him to make war on the rat until it is exterminated.

**277. The Hog.** — The hog carries two parasites which affect the health of man: viz., the tapeworm and the trichina. The eggs of the tapeworm are eaten by the hog. These hatch within its stomach and pass through the walls of the digestive organs and find their way into the muscle of the hog. If these microscopic worms in the muscle of the hog are eaten by man while the meat is uncooked, the worm will be released by the digestive juices and will attach itself to the walls of the digestive organs and become a parasite of man, where the worm increases in length and width, sometimes attaining a length of 40 feet. A tapeworm can also be taken into the body from raw beef and mutton.

A person may contract the disease known as *trichinosis*, caused by the trichina, by eating raw pork. The microscopic worm incloses itself within the muscles of the hog and when eaten the juices in the digestive organs of man release it and it finds its way out of the digestive organs into the muscles, where it produces inflammation. The disease is very often fatal.

**278. Hookworm.** — The hookworm disease is common in the poorer sections of the Southern states. The worm requires a warm climate in order that it may live over the winter in the soil. While young, it is microscopic in size and enters the body through the soles of the feet of those



HOOK WORMS  
Actual size.  
(Adults)

people who do not wear shoes during the warmer season. It finds its way into the blood vessels and is carried to the heart and thence to the lungs; it then passes out into the air tubes and is coughed up into the throat and swallowed. It attaches itself to the inside of the digestive organs, where it lives as a parasite on man, producing laziness, lack of ambition, and a loss of desire for bettering his condition. The disease can be cured with about fifty cents' worth of medicine and a pair of shoes to prevent the reentrance of the worm, but the people must also be taught to be clean about their homes and also to continue wearing shoes during all seasons of the year. The greatest task in the way of curing the southern people of this disease is in educating the people who have no desire for anything better and who lack ambition. Educating such a group of people is a very slow and difficult process and since they do not have the means and a desire for getting it, education is also a very expensive process. John D. Rockefeller has given more than one million

dollars to help remove this disease from the people in the South.

#### QUESTIONS AND EXERCISES

1. What disease does the house fly carry? How can it be prevented? Where do flies live during the winter?
2. Find some mosquito eggs, larvæ, pupæ, and adults. How can the mosquito be destroyed? What diseases do some mosquitoes carry? Are there any disease-carrying mosquitoes in your community?
3. Give reasons why rats should be destroyed.
4. What diseases may be contracted by eating raw pork and beef? Is dried beef raw?

## CHAPTER XLI

### MAN'S PLACE IN NATURE

**279.** Man is the climax of the whole creation series. He has conquered all other animals, not by physical force, but by the power of his brain, which makes him able to build places for protection and also machines both for protection and for doing various kinds of work which would be impossible for him to do with his hands. By using clothing, houses, and fire man is able to adapt himself to all climates, varying from the intense heat at the equator to the severe cold at the poles.

Man has learned to eat a great variety of plant and animal foods, which during primitive times he gathered from plants growing wild and from wild animals. He gradually learned how to cultivate plants and to domesticate animals. The plants and animals have been so changed and improved by selection and careful breeding, that one man now can grow sufficient plants and animals to feed many people. The process of improvement by careful selection and breeding has only begun, and greater results will be accomplished in the future by the application of man's intelligence and good judgment to methods of husbandry. Man is using all the available known forces of nature to maintain his own existence.

The greatest enemies which man must fight are not the large animals or large plants; these he learned long ago to subdue with his invented machines. The animals

and plants which are most destructive to mankind are the ones which are so small that a microscope is needed to find them. These animals and plants which have become parasites to man produce many dangerous diseases; and unless man is able to adapt himself to the conditions which these parasites produce, or can exterminate them by preventing their growth, they will greatly hinder his progress or may even exterminate him. In order to cope with these germs it is necessary for every person to use all the knowledge which he possesses concerning how to live so that he may keep himself clean, healthy, and free from all germs. The blood of most healthy people is able to kill nearly all disease germs as fast as they get into their bodies. A person who is indulgent in several ways, or who is in other than good health, cannot expect to be immune from the attacks of disease germs. In order to have good health we should be as regular as possible in our habits of rest, exercise, and times for eating. The environment of the places where we rest (sleep), exercise (work), and take our meals has a great influence upon health. Since man is by nature endowed with the capacity to select or to modify his environment to some extent, it is necessary for him to make it as favorable as possible for his existence.

The way to change our environment is to remove all filth and decaying matter from our homes, have the rooms properly ventilated, lighted, and heated, make our homes attractive and beautiful inside and outside, with flowers and decorations of various kinds, and see that the sources of water supply such as springs and wells are properly covered and protected from contaminating sources.

**280. Selecting a Home.** — Since so many people change their location every year, it is very important that all

should know what kind of an environment to select. In choosing a locality for home-making or a place in which to live, the social or human environment should perhaps receive first consideration, because the social environment is usually the hardest to change. The next to receive consideration is the nearness to swamps or standing water where mosquitoes can breed; then the following: good drainage about the home in order to carry off surface water quickly, proper elevation with reference to the immediate surroundings, kind of water and the quantity available for household purposes, nearness to factories or other undesirable institutions that hinder the comforts of a happy home.

#### QUESTIONS AND EXERCISES

1. How does man differ from other animals?
2. What are the greatest enemies of man? What methods are used to overcome them?
3. What are the most important things to consider in selecting a location for a home?

## CHAPTER XLII

### THE EARTH AND ITS NEIGHBORS

**281. The Earth is Very Old.** — During the past hundred years men have studied the rock formations of the earth, the causes of volcanoes, mountain-making, and the rapidity with which the mountains are worn away by the process of erosion. The facts which have been thus collected show that the earth is many millions of years old. Mountains have been made by a gradual upheaval of the earth's surface, caused by expansion due to heat. Mountains have also been made by the flow of lava from volcanoes and cracks in the earth or sides of mountains.

The Appalachian Mountains in the eastern part of the United States are very old and were once much higher than they are at present. The Potomac, Susquehanna, and Juniata rivers seem to have cut across the mountain ridges as fast as the ridges were elevated; this is shown by the gaps in the mountains through which these streams flow. These gaps make the construction of roads and railroads very easy. They save the trouble of going through the mountains or over them.

The Rocky Mountains, although about three million years old, are young when compared to the Appalachians. The Rockies are still in the process of formation. Earthquakes are frequent along the western coast and the volcano in northern California which has recently been active.

ejected a large amount of lava and mud which covered a large area; these are evidences of mountain-making.

These mountains are old, but the coal which is now mined in the Appalachian and Rocky Mountains is older and was formed long before the mountains were made. This gives us a suggestion that the earth is many millions of years old.

**282. The Earth and Sun:** — During these millions of years while the earth was in process of changing its surface, it has been moving around the sun, from which it gets heat and light. The path of the earth around the sun is called the earth's orbit. The time required for the earth to go once around its orbit is called a year. This orbit, though not quite circular, is about 184,000,000 miles in diameter, and the sun is always approximately 92,000,000 miles distant. The diameter of the earth is about 8,000 miles and the diameter of the sun is about 860,000 miles.

**283. The Earth and Moon.** — The moon is a spherical body which moves around the earth and it is about 240,000 miles distant and about 2,000 miles in diameter. The moon has mountains and volcanic peaks on it; these can be seen with a large telescope. There is no evidence of any water or life on the moon. The moon goes around the earth once in 28 days, making a lunar month, and it turns once on its axis during the same time, and on that account always keeps the same part turned toward us. The moon's phases are due to its positions with respect to the sun. When the moon and sun are in the same direction from us, the moon is said to be dark and cannot be seen because it passes across the sky with the sun; during this time the sun is shining on the part of the moon turned away from us. When the sun and moon are in opposite directions, or nearly so, from us the moon passes across

the sky at night and the part which is illuminated by the sun is turned toward us and reflects the sun's light to us the same as the wall of a building will reflect light. When all of the moon which is illuminated by the sun can be seen, the moon is said to be full. When only one-half of the illuminated part can be seen, it is called first quarter during the light of the moon and last quarter during the dark of the moon. The period known as "light of the moon" lasts 14 days, extending from "new moon"

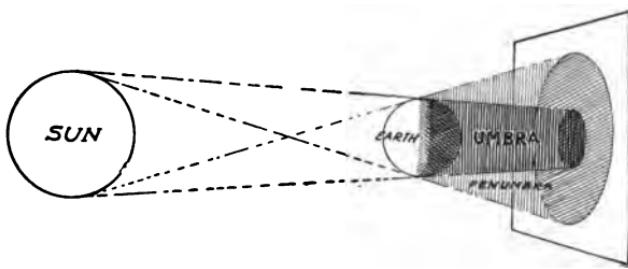


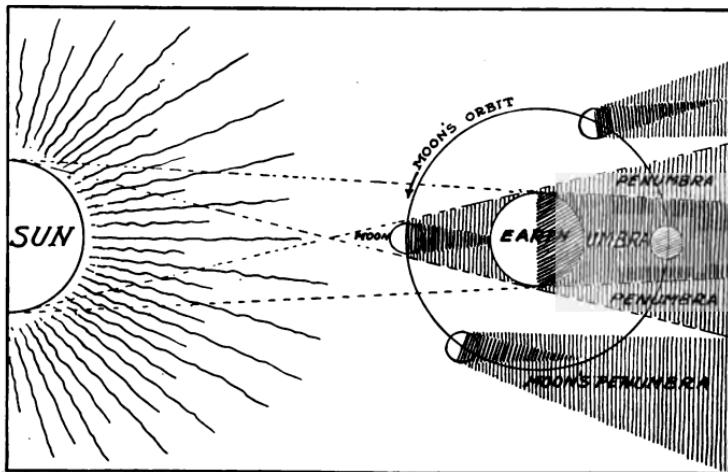
DIAGRAM OF AN ECLIPSE

Showing why an object casts a shadow of two intensities when in the presence of a large luminous body like the sun.

to "full moon," during which time the visible illuminated part is increasing in size. The period known as "dark of the moon" also lasts 14 days, during which time the visible illuminated part is decreasing in size.

**284. Eclipse of Sun and Moon.** — The earth and moon, like all opaque objects, cast a shadow in the direction opposite the sun. Since the sun is very large, being 100 times the diameter of the earth and 400 times the diameter of the moon, the shadows of the earth and moon come to a point and are cone-shaped. The average length of the earth's shadow is 856,000 miles and that of the moon is 232,000 miles. When the moon happens to pass through the earth's shadow at night, a part or all of it is invisible

and it is then said to be eclipsed. In the day time when the moon is close enough so that its shadow reaches the earth, the sun is hidden from view in that area on which the moon's shadow falls, and then the sun is eclipsed. Since the diameter of the moon's shadow where it touches



ECLIPSES OF SUN AND MOON

Showing how the sun is eclipsed by the shadow of the moon reaching the earth and how the moon is eclipsed when it passes through the shadow of the earth.

the earth is small, most of the eclipses of the sun are only partial; occasionally a total eclipse occurs.

**285. The Planets.** — There are other bodies moving around the sun besides our earth. Seven of these bodies and the earth are called planets. Each one of these planets has a name of its own. Two of the planets are closer to the sun than the earth and five of them are farther away. In the order of their distance from the sun they are as follows: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The outer ones

are so far from the sun that they do not receive much heat and light.

The time it takes for these planets to go once around the sun is given in the following table with the distance of each from the sun. The time is represented in number of earth's days and years.

<i>Planets</i>	<i>Time for one revolution</i>	<i>Distance from the sun</i>
Mercury.....	88 days.....	36 million miles
Venus.....	225 days.....	67½ " "
Earth.....	365½ days.....	92 " "
Mars.....	687 days.....	141½ " "
Jupiter.....	11½ years.....	483½ " "
Saturn.....	29½ years.....	886 " "
Uranus.....	84 years.....	1780 " "
Neptune.....	165 years.....	2790 " "

These planets with the sun compose the solar system. The entire solar system is moving through space and is one system among hundreds of others. The distant stars are suns much larger than our sun, and each one is at the center of a system of its own. The earth itself is but a small particle of matter when compared with all the matter in the universe.

Mercury and Venus do not have moons or satellites. The earth has one, Mars has two, Jupiter has five, Saturn has nine, Uranus has four, and Neptune has one satellite. These moons move around the planets in much the same way as the planets move around the sun. The moons are not self-luminous, but only reflect the light received from the sun the same as objects on the earth reflect light to our eyes.

**286. The Stars.** — The stars other than the planets are at a very great distance from us, so far that telescopes do not make them look much larger than they do to the unaided eye. When the planets are viewed with a good

telescope, they appear like huge balls illuminated. Some of their moons can also be seen.

It takes about eight minutes for the light to come from the sun to the earth, a distance of about ninety-two million miles. This means that light travels at the enormous speed of 186,000 miles per second, or seven and one-half times around the earth if it could go in a curved line.

The stars other than the planets are called fixed stars, and the nearest of these, Alpha Centauri, is so far away that 4.4 years are required for the light to come from it to the earth. It takes about 45 years for the light to come from the North Star. Some of the stars are so far away that several hundred years are required for the light to reach the earth.

**287. Meteors.** — Meteors are also known as "shooting stars." Some are composed mostly of iron and others of stone. They vary in size from small shot to hundreds of pounds. One found in Texas weighs 1635 pounds; it is now in the Peabody Museum of Yale University. The same museum has hundreds of smaller ones also. Other museums in the United States and Europe contain thousands of meteorites.

Meteors are flying through space at a speed of about 35 miles per second, and when they strike the earth's atmosphere they are made white hot by the impact and by the friction produced while passing into the air. They strike the earth's atmosphere by the million every day, but nearly all are vaporized before they penetrate very far and never become visible. Those which are large enough to be seen rarely become visible until they are within 70 miles, and usually disappear before they come within 30 miles of the earth. Only a few have been seen to fall

to the earth. In 1866 a shower of small meteors fell in the western part of the United States.

#### **QUESTIONS AND EXERCISES**

1. What evidence can you see that the earth is very old? How were the hills, valleys, and plains made? When were coal, petroleum, limestone, and chalk formed?
2. What causes the phases of the moon? Why is the moon sometimes eclipsed? What causes an eclipse of the sun?
3. What planets are going around the sun other than the earth?
4. If you were on the moon, how would the earth appear to you?
5. What is the nature of a meteor or "shooting star"? Where are they when they are visible?



## APPENDIX

### THE METRIC SYSTEM

**Historical.** — The Metric System is an outgrowth of the French Revolution of 1789. At that time there was a general disposition to break away from old customs; and the Revolutionists contended that everything needed remodeling. A commission was appointed to determine an invariable standard for all measures of length, area, solidity, capacity, and weight. After due deliberation, an accurate survey was made of that portion of the terrestrial meridian passing through Paris, between Dunkirk, France, and Barcelona, Spain; and from this, the distance on that meridian from the equator to the pole was computed. The quadrant thus obtained was divided into ten million equal parts; one part was called a *meter*, and is the base of the system. From it all measures are derived.

France adopted The Metric System in 1795. It is now used in nearly all civilized countries. It was authorized by an act of Congress in the United States in 1866.

The Metric System is a decimal system of weights and measures. The meter is the primary unit upon which the system is based, and is also the unit of length. It is 39.37 inches long. The standard meter, a bar of platinum, is kept among the archives in Paris. Duplicates of this bar have been furnished to the United States.

The names of the lower denominations in each measure of the Metric System are formed by prefixing the Latin

numerals, deci (.1), centi (.01), and milli (.001) to the unit of that measure; those of the higher denominations, by prefixing the Greek numerals, deka (10), hekto (100), kilo (1000), and myria (10,000), to the same unit. These prefixes may be grouped about the unit of measure, showing the decimal arrangement of the system, as follows:

Lower Denominations	$\left\{ \begin{array}{l} \text{milli} = .001 \\ \text{centi} = .01 \\ \text{deci} = .1 \end{array} \right.$
Unit of Measure	= 1.
Higher Denominations	$\left\{ \begin{array}{l} \text{deka} = 10. \\ \text{hekto} = 100. \\ \text{kilo} = 1000. \\ \text{myria} = 10000. \end{array} \right.$

The units of the various measures, to which these prefixes are attached, are as follows:

- The Meter, which is the unit of Length.
- The Liter, which is the unit of Capacity.
- The Gram, which is the unit of Weight.

The name of each denomination thus derived, immediately shows its relation to the unit of measure. Thus, a centimeter is one one-hundredth of a meter; a kilogram is a thousand grams; a hektoliter is one hundred liters, etc.

**Measure of Length.** — The *Meter* is the unit of Length, and is the denomination used in all ordinary measurements.

10 millimeters, marked mm.	= 1 centimeter, marked cm.
10 centimeters	= 1 decimeter, " dm.
10 decimeters	= 1 meter, " m.
10 meters	= 1 dekameter, " Dm.
10 dekameters	= 1 hektometer, " Hm.
10 hektometers	= 1 kilometer, " Km.
10 kilometers	= 1 myriameter, " Mm.

The centimeter and millimeter are most often used in measuring very short distances; and the kilometer, in measuring roads and long distances.

**Measure of Capacity.** — The *Liter* (pro. *le'ter*) is the unit of Capacity. It is equal in volume to a cube whose edge is a decimeter; that is, one-tenth of a meter.

10 milliliters, marked ml.	= 1 centiliter, marked cl.
10 centiliters	= 1 deciliter, " dl.
10 deciliters	= 1 liter, " l.
10 liters	= 1 dekaliter, " Dl.
10 dekaliters	= 1 hektoliter, " Hl.

This measure is used for liquids and for dry substances. The denominations most used are the liter and hektoliter; the former in measuring milk, vinegar, etc., in moderate quantities, and the latter in measuring grain, fruit, etc., in large quantities. Instead of the milliliter and the kiloliter, it is customary to use the cubic centimeter and the cubic meter (marked  $m^3$ ), which are their equivalents.

**Measure of Weight.** — The *Gram* is the unit of Weight. It was determined by the weight of a cubic centimeter of distilled water, at the temperature of maximum density ( $39.2^\circ$  F.) or  $4^\circ$  C.

10 milligrams, marked mg.	= 1 centigram, marked cg.
10 centigrams	= 1 decigram, " dg.
10 decigrams	= 1 gram, " g.
10 grams	= 1 dekagram, " Dg.
10 dekagrams	= 1 hektogram, " Hg.
10 hektograms	= 1 kilogram, " Kg.
10 kilograms	= 1 myriagram, " Mg.
10 myriagrams or 100 kilograms	= 1 quintal, " Q.
10 quintals, or 1000 "	= 1 metric ton, " M.T.

The gram, kilogram (pro. *kil' o-gram*), and metric ton are the weights commonly used. The gram is used in all

cases where great exactness is required; such as, mixing medicines, weighing the precious metals, jewels, letters, etc. The kilogram, or, as it is commonly abbreviated, the "kilo," is used in weighing coarse articles, such as groceries, etc. The metric ton is used in weighing hay and heavy articles generally.

Since, in the Metric System, 10, 100, 1000, etc., units of a lower denomination make a unit of the higher denomination, the following principles are derived:

*Principles.* — 1. A number is reduced to a lower denomination by removing the decimal point as many places *to the right* as there are ciphers in the multiplier.

2. A number is reduced to a higher denomination by removing the decimal point as many places *to the left* as there are ciphers in the divisor.

The following table presents the legal values of those denominations of the Metric System which are in common use.

<i>Denomination</i>	<i>Legal Value</i>
Meter.....	39.37 inches
Centimeter.....	.3937 inch
Millimeter.....	.03937 inch
Kilometer.....	.62137 mile
Ar.....	119.6 sq. yards
Hektar.....	2.471 acres
Square Meter.....	1.196 sq. yards
Liter.....	1.0567 quarts
Hektoliter.....	2.8375 bushels
Cubic Centimeter.....	.061 cu. inch
Cubic Meter.....	1.308 cu. yard
Ster.....	.2759 cord
Gram.....	15.432 grains troy
Kilogram.....	2.2046 pounds av.
Metric Ton.....	2204.6 pounds av.

## GLOSSARY

**Abnormal**, not normal. Abnormal foods are those which are not well prepared, excessively spiced or sweetened, and things which are not necessary but may be an injury. Pies, some cakes, tea, and coffee are examples.

**Al'ka loid**, a substance having an alkaline or basic property, found in plants, usually combined with such acids as tannic, malic, or citric. Examples are caffeine, theobromine, morphine, cocaine, quinine, etc. Some alkaloids are stimulants and some are narcotics.

**Am mo'ni um hy drox'ide**, a basic compound made by forcing ammonia gas into water. Household ammonia is an example.

**Bac te'ri a** (singular, *bac te'ri um*), one-celled plants so small that a good microscope is needed to see them. Most of them have to be stained before they can be seen individually. Some cause disease, some are harmless, and many kinds are useful.

**Bear'ings of a machine**, the fixed parts or shafts on which wheels turn. A wagon has sliding bearings, a bicycle has ball bearings, and many automobiles have roller bearings. Oil is placed on the bearings so that the wheels will turn without much friction or resistance.

**Bordeaux' mixture** (*bōr do'*), a mixture of copper sulfate, quicklime, and water. For plants with tender leaves, dissolve two pounds of copper sulfate in 45 gallons of water, slake two pounds of quicklime in 5 gallons of water; then mix the two solutions.

**Cal'ci um**, a pale yellow metal; a simple substance. It is found in nature combined with other elements. It is one of the component parts of lime, limestone, and marble.

**Cap il lar'i ty or capillary attraction**, the peculiar action by which the surface of a liquid, where it is in contact with a solid, is elevated or depressed. Water adheres to the sides of a small tube to such an extent that it is drawn up the tube. This is one of the forces which cause sap to flow up in a tree.

**Car'a mel**, partially burnt sugar. It can be made by heating sugar to 200° C. for a few minutes. The brown color of bread crust is caused by the formation of caramel during baking.

**Car'bon mon ox'ide**, a gas formed when carbon gas is only one-half oxidized. It is very poisonous.

**CC. or C. C.**, a cubic centimeter.

**Con ser va'tion**, a process of guarding, protecting, or saving force, energy, and resources. To prevent the waste of our forests, coal, and iron ore is conservation.

## GLOSSARY

**Consumption of a gas**, to burn it in order to make heat or light, or to use it for making compounds. Green plants consume carbon dioxide gas of the air when they make starch. Animals consume oxygen when they breathe.

**Con tam'i nate**, to infect with poisons, filth, or with disease germs. Surface water from a house or barn flowing into a well by a short passage may contaminate the water and render it unfit for use.

**De com pose'**, to separate into simpler substances or parts. To decompose water is to separate it into hydrogen and oxygen. Plants decompose when they decay.

**Den'si ty of a substance** is the ratio of its weight in grams to its volume in cubic centimeters. One cubic centimeter of water weighs one gram, hence its density is one.

**Di'a phragm**, a large thin muscle which forms a partition between the lungs and digestive organs of the human body and assists in breathing. It is arched upward, and when it contracts the chest cavity is enlarged and air rushes in to fill the lungs.

**Di'a stase**, a ferment found in cereal grains. It changes starch to sugar when the temperature is right and sufficient moisture is present. When conditions are favorable for plants to grow, diastase can act.

**Digestive fluid**, a fluid which contains ferments that make food soluble in water. Examples. — Saliva in the mouth, gastric juice in the stomach.

**Di lute'**, to make less strong or less concentrated. Vinegar, ammonia, and alcohol may be diluted by adding water.

**Dis so lu'tion**, the process of dissolving a crystallized substance in a liquid. Sugar and salt can be dissolved in water. Heat is often required to dissolve a substance.

**Dis til la'tion**, the process of separating a substance which vaporizes easily from one or more substances which vaporize less easily. The vapor, caused by adding heat, is liquified or condensed while passing through pipes which are kept cool by water flowing over them.

**Elec tro mo'tive force** (*abbr. E.M.F.*), the force which drives an electric current. It is the difference in potential or electrical pressure at two points on an electric circuit. The *volt* is the unit of electromotive force.

**En vi'ron ment** consists of the things and conditions around you which may affect your life. It consists of weather, climate, plant life, animal life, and the social conditions made by man. Students in high school adjust themselves to the conditions made by themselves and their teachers, and to the changes in the weather.

**En'zyme** (*ĕn'zim*), a general name for a number of chemical, digestive ferments, such as diastase found in cereals, pepsin and rennin found in the gastric juice of the stomach, and ptyalin in the saliva.

**Ex'cre to ry organs** are organs which take poisons and useless matter from the body. Examples are the kidneys, liver, lungs, etc.

**Fehling's solution**. (Named after Hermann Fehling (1812-1885), a German chemist.) It is made by dissolving one part by weight of

copper sulfate (blue vitriol) in 14.3 parts by weight of water. (Several hours are required for it to dissolve.) Mark this solution No 1. Dissolve one part by weight of caustic soda and 1.081 parts of Rochelle salt in 3.12 parts by weight of water. Mark this solution No. 2. For use mix equal parts of 1 and 2. When it is heated with certain sugars, red cuprous oxide is formed, giving the characteristic red color for the sugar test.

**Fer'ment**, an agent capable of producing fermentation or chemical changes like those produced by yeast plants, diastase, bacteria, etc. (See diastase and enzyme.)

**Func'tion**, the use of any organ or part of an animal to the animal itself.

The same application may be made to plants.

**Fu'sion**, the process of changing a solid to the liquid condition by means of heat. Some substances fuse at low temperatures and others at very high temperatures.

**Gly'co gen**, a white, tasteless carbohydrate, related to starch and dextrin sugar. It is found in the liver of animals and is sometimes called animal sugar, and animal starch.

**Grafting wax**, a wax used for holding grafting scions in position until they grow. To make it: Melt together one pound of resin, one-half pound of beeswax, one-fourth pound of tallow. Stir it for a few minutes while hot. Pour the mixture into cold water. Grease your hands and pull the wax until it has a straw color.

"**High**" on a weather map means that the barometers in that area read higher than those which are more distant from that center. Fair weather usually follows in an area marked "high."

**Hu'mus**, the decaying plant and animal matter of the soil. It usually gives the soil a dark color and is one of the principal sources of plant food.

**I'o dine**, a simple substance; an element blackish gray in color. It dissolves readily in alcohol and the solution is reddish violet in color. In dilute form it turns starch to a purple color.

**Lime** is made by heating limestone ( $\text{CaCO}_3$ ) to a white heat for about two days in a limekiln to drive off the carbon dioxide. The solid matter taken from the limekiln is calcium oxide ( $\text{CaO}$ ) or commercial unslaked lime.

**Lime-sulphur spray**, a spray made by boiling a mixture of quicklime and sulphur in water for an hour; 15 pounds of each to 50 gallons of water.

**Linear**, when applied to objects means long, slender ones which are comparatively uniform in width. Linear expansion refers to the expansion in the direction of length.

"**Low**" on a weather map means that the barometers in that area read lower than they do at points more distant from that center. Cloudy and rainy weather usually follow in a "low" area.

**Mechanical advantage** of a block-and-tackle is an even or odd number according to whether the rope is first fastened to the fixed or movable pulleys respectively.

## GLOSSARY

**Mer'cu ry**, a silver-white liquid metal. It freezes at  $-39.5^{\circ}$  C. and boils at  $357^{\circ}$  C. Mercury ore (cinnabar) is mined in Spain, Austria, Italy, and in California and Texas. It is separated from the ore by roasting in closed ovens and then condensing the vaporized mercury. It is also known as quicksilver.

**Mil'let**, a grain grown in Europe and Asia for food for both animals and man. Millet is also a general name for a number of small grains. The variety grown in the United States is usually cut green and fed as hay.

**Mo'ment of a force** is the tendency of that force to produce motion about a point or axis. It is the product of the force times the perpendicular distance from the point to the line of direction of the force. If a horse is pulling with a force of 400 pounds on a windlass lever 10 feet long, the moment is 4000.

**Neutral substances**, those which do not have characteristics like acids or bases. Common salt and pure water are examples.

**Nu'tri ents**, the three divisions made of nutritious foods, namely, carbohydrates, fats, and protein.

**Nu'tri ment**, a food which promotes growth and repairs the natural waste of animals and plants. Some nutriments contain all three nutrients.

**Ores** are compounds taken from the earth and contain one or more valuable metals, such as iron, copper, mercury, silver, gold, etc.

**Or'gan ism**, a living body, as a plant or animal. It may be made up of organs, tissues, and cells. A one-celled animal or plant is an organism.

**Phe nol phthal'e in** (*fe nol thal'e in*), a very complex substance that cannot be made in the ordinary laboratory. If purchased in dry form, dissolve one gram in 100 c.c. of 96 per cent alcohol. Dilute bases turn colorless phenolphthalein to a red color and acids change it back to colorless condition. As a test for acids and bases it is much more delicate than litmus.

**Phos'phor us**, a simple chemical element which oxidizes very readily. Yellow phosphorus (a phosphorus oxide) must be kept under water and not handled with bare fingers in the open air. Cut it under water. Red phosphorus (a phosphorus oxide) is not so dangerous, and ignites at  $260^{\circ}$  C. Phosphorus is used in the manufacture of matches, and for fertilizer in the form of phosphoric acid.

**Piston**, the sliding piece in the cylinder of an engine or pump. The rod attached to it is the piston rod. In an engine the piston is moved by steam or other gas; in a pump it is moved by the force applied to the handle of the pump.

**Platinum electrode**, a piece of sheet platinum in an apparatus for decomposing water. The electricity passes into the water by one electrode and leaves the water by the other electrode.

**Pneu mat'ic trough** (*nu mat'ik*), an open-topped vessel with a shelf in it for supporting inverted bottles full of water in such a way that a tube may be inserted for catching a gas. (See illustration on page 48.)

## GLOSSARY

**Pre cip'i tate**, an insoluble compound formed sometimes when soluble compounds are poured together. If hydrochloric acid is added to a solution of lead nitrate a white precipitate of lead chloride will be formed.

**Ra'di um**, an intensely radio-active, metallic element found in minute quantities in pitchblend and carnotite. Some is found in the state of Colorado. It has the property of giving off light, etc.

**Rare air**, air that weighs less per unit volume than air at sea level, or air that is less dense than some other air. A cubic foot of air on top of a mountain three miles high weighs only one-half as much as a cubic foot of air at sea level.

**Refrig er a'tion**, a process by which foods are kept at a low temperature so that they do not spoil very rapidly. Meat, eggs, fruit, and vegetables are often kept in cold storage or refrigerator rooms.

**Retting**, a process of preparing flax plants by soaking them in water. It causes the soft parts of the stems to decay and then the fiber is combed.

**Sa li'va**, the digestive fluid secreted by six small glands and poured into the mouth in large quantity while one is eating; at other times a sufficient amount is secreted to keep the mouth moist. It contains an enzyme, — ptyalin, — which can change starch to sugar.

**Saturated solution**, a liquid containing as much of another substance as it can hold in solution. When water has all the dissolved salt or sugar that it can hold, it is a saturated solution.

**Sed'en ta ry**, when applied to a man, means one who does not take much physical exercise. Bookkeepers and stenographers lead a sedentary life. They should take exercise in the open air when possible.

**Seedling**, a young plant in the germinating stage.

**Si'sal**, a kind of hemp of which rope is made. It grows in Mexico and in Central America.

**Ster'i lize**, to treat tools and substances in such a way that living organisms, disease germs, are killed. Boiling water and chemicals are used for this purpose.

**Tho rac'ic duct** (*tho ras'ik*), a tube just inside the spinal column. It extends from back of the middle of the digestive organs to the left side of the neck, where it connects with a large vein coming down from the head. The digested fat, and lymph (a milky-colored liquid from many parts of the body) pass into the blood through this tube.

**Volt**, a unit of electromotive force. It is an electromotive force which will drive a current of one *ampere* over a conductor which has a resistance of one *ohm*.

**Water sprouts**, branches which appear around the base or on large limbs of trees. They should not be left on trees because they make them too bushy, waste the food of the trees, and bacteria diseases can easily enter the trees through them.

**GLOSSARY****Names of Some Common Chemical Elements and Their Symbols**

Calcium .....	Ca.	Nitrogen.....	N.
Carbon .....	C.	Oxygen.....	O.
Chlorine.....	Cl.	Phosphorus.....	P.
Copper.....	Cu.	Potassium.....	K.
Hydrogen.....	H.	Sodium.....	Na.
Iodine .....	I.	Sulphur .....	S.
Iron.....	Fe.	Zinc.....	Zn.
Mercury.....	Hg.		

## SUGGESTIONS FOR TEACHERS

**General Suggestions.** — Please keep in mind that students are being taught and that the subject matter must be adapted to their capacity and needs. Study the experiences and needs of the students and make the subject a living one by presenting it to them in such a way that they will begin to use it immediately. Connect it with their everyday life by drawing on their experiences and home environment. Whenever possible have the students bring the material for classroom use, and have them prepare everything possible. The duty of the teacher is to keep the students busy at something useful.

The questions and exercises at the close of each chapter will give some suggestions for detailed procedure. Some detailed suggestions for the treatment of a few chapters follow:

**Chapter III.** — Before assigning any work in this chapter give the students some red and blue litmus paper and have them test many of the substances which they have at home, arranging the compounds in three columns, namely:

Tell them that those substances which turn blue litmus paper to a red color are acids, those which turn red litmus to blue are bases, and those which do not affect either red or blue litmus are neutral compounds.

Have them test such compounds as water, milk, lard, vinegar, baking soda, soap, alcohol, etc.

Lime water can be made by placing about one pound of unslaked lime in four pints of water. Use a tall vessel and shake well after slaking the lime and set it aside for a day or more, so that the undissolved lime can settle, then pour off the clear lime water into a bottle for future use.

A potash-lye solution may be made of the lye purchased in grocery stores by dissolving it in water. Household ammonia and baking soda may also be obtained from the grocery.

These bases with vinegar, sour milk, and fruit juices for acids will be sufficient material for classroom demonstration to show the nature of such compounds. If you have an equipped laboratory use the chemicals at your disposal, but be sure that you connect the work with the life of the students.

Have the students make soap at home and bring the finished product to school. Give them the directions for making the soap and supply a small quantity of lye if you have it.

Have the students test their home water to learn whether it is hard or soft.

or soft. Have them find whether it is cheaper to soften water with soap or with washing powder, etc.

**Chapter IV.** — Have each student bake some biscuits by using the baking chemicals as follows:

- (1) By using baking soda without any acid.
- (2) By using baking soda with sour milk.
- (3) By using baking soda with vinegar or hydrochloric acid.
- (4) By using baking powder with vinegar or sour milk.
- (5) By using baking powder without any acid.
- (6) By dissolving the baking powder in water and then mixing the solution with the material to be baked.

Have the students bring their products to school and explain why such different results were obtained.

**Chapter VI.** — The first assignment in this chapter should be as follows:

- (1) Define stimulant.
- (2) Name some common stimulants.
- (3) Make a list of all the good effects which come from their habitual use.
- (4) Make a list of the evil effects which come from their habitual use.

During the recitation have the students freely discuss the topics, but with the teacher always in control. The teacher should present additional facts and then let the students draw their own conclusion.

Treat the subject of narcotics by the same method.

**Chapter XIX.** — Let the environment of the school determine to what extent you require the students to master this chapter. Use sufficient details to enable the students to understand the simple machines which they have already used. Always draw upon their experiences and use these as a basis on which to build. Have them report on where they have seen levers, inclined planes, pulleys, etc., used. Let them explain how these machines were being used.

**Chapter XXXII.** — Have the students examine some soil and bring some to class for more careful examination. Have students bring roots of clover or similar plants and examine the tubercles. Have a student make a report to the class on nitrogen compounds used for fertilizer. Have them visit gardens and farms to see how soil is treated while caring for plants.

**Chapter XXXIV.** — Have all students plant at home such seeds as beans, pumpkin seeds, corn, peas, etc., in soil, sawdust, or sand to learn how such seeds start to grow and to learn the necessary conditions for healthy germination of such seeds. In a village or country high school germinating tests of seeds should be made by taking six grains from various places on an ear of corn and placing them in proper germinating conditions. If all six grains grow the ear should be saved for seed.

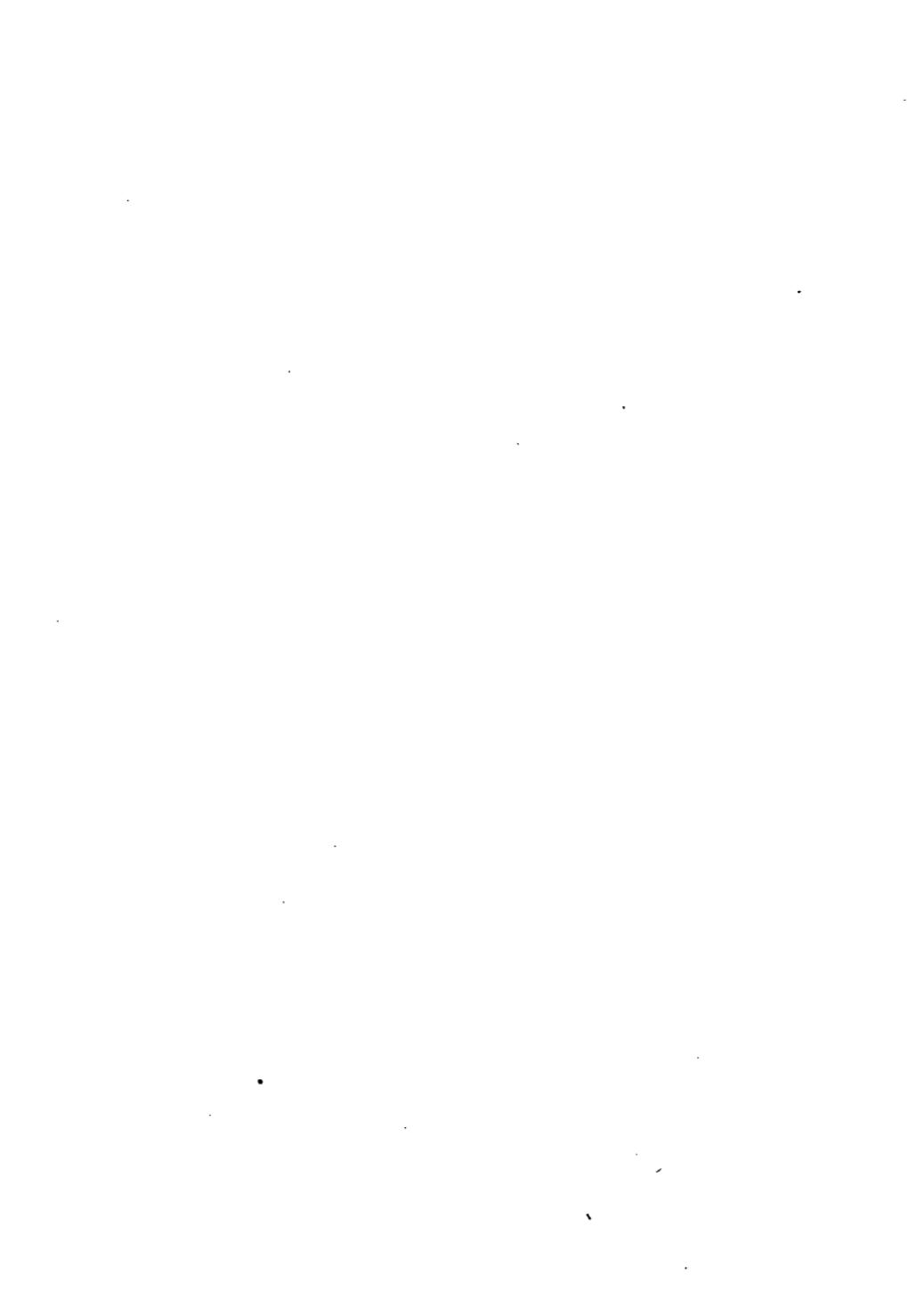
To make a seed germinating tester, take a box a foot or more square and about two inches deep. Stretch wires across both ways, making two-inch squares. Fill the box with soil up to the wires and cover the

soil with a cloth by placing the cloth under the wires. Number and letter the squares on two adjoining sides respectively. Then every square can be located by using a number and a letter. Take six grains from each ear of corn to be tested and place them in the squares and at the same time place a label composed of a number and a letter on each ear, indicating where its six grains are. After the tester has seeds in each square, cover it with damp cloths and keep them damp, also keep the tester in a warm room. Discard all ears that do not give a 100 per cent test.

Other seeds may be tested the same as corn.

**Chapter XXXVIII.** — Have students bring to class all kinds of raw fruit and branches of fruit trees, and examine them carefully for diseases and animal pests. Have them bring in old fruit which dried on the trees and examine for brown-rot. If this dried fruit (mummies) shows any development of brown spores after it is kept moist in a warm room for a week or more, brown-rot is present.

Examine other plants for diseases and pests.



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